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THE UNIVERSITY OF ALBERTA

PHYSIOLOGICAL AND PERFORMANCE CHANGES DURING A SEASON OF TEAM HANDBALL

by

© RON GORGICHUK

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

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A.B. Nielsen
External Examiner

Date April 24/81

DEDICATION

This work is dedicated to the people who have contributed to my perception of reality. Through this perception I have chosen a set of presuppositions which are both logical and applicable to the realities of my life.

My perception stands in a system of coordinates that are set by the external world, the Christian Scriptures, the continuity of time and the scope of all men across the world and throughout history. Collectively, these entities provide controls on each other, so that together they present a view of reality that is more accurate than any one of them, or than my perception of any one alone.

ABSTRACT

The purpose of this study was to determine if any significant change occurred in selected physiological and performance test results of Top Competitive Team Handball players over the course of a regular season. Further, it was hoped that descriptive physiological and performance data could be collected and used to describe Top Competitive Team Handball players as a team and in accordance to the positions played.

Data was collected and changes were measured on the following variables: maximal oxygen uptake, anaerobic capacity, per cent body fat, distance jump, vertical jump, 10m sprint time, 40m sprint time, shot velocity and weight.

Ten top competitive Team Handball players from Alberta's Provincial Senior Mens Team Handball Team, acted as subjects for the study.

From this study it was concluded that a significant difference occurred at the .05 level, between the beginning and the end of season means for the aerobic power variable. No significant difference at the .05 level was found for any of the other variables.

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Above all, thanks to the Personal Infinite Creator of the Universe for creating me in His image, with the ability to reason and providing the reasons for living and for life.

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TITLE

Physiological and Performance Changes During a Season of Team Handball

CHAPTER I

STATEMENT OF PURPOSE

INTRODUCTION

Tremendous progress has been made in the sport of Team Handball, both in its acceptance as an exciting international spectator sport and in the overall quality and calibre of play shown by today's world class teams. This progress, it is assumed, will continue as a result of the strength and interest of the various organizations which govern Handball nationally and internationally.

North America, although experiencing rapid growth in a few regions, is not enjoying the same degree of progress one finds in Europe. One of the primary reasons for this lesser progress, it seems, is the lack of sufficient knowledge and understanding of the sport.

Scientific research and related documentation which can provide fundamental understanding of the various technical elements of the sport, is almost non-existent.

Without this basic understanding, technical development in coaching, and more specifically, individual and team selection and preparation in Canada will continue to lag appeciably behind the European standards. In Canada the primary link in the Team Handball delivery system is the Provincial Team Handball Association. Each year the top Team Handball athletes in each province are brought together by provincial coaches in preparation for the annual Canadian Championship in May.

Provincial Team preparations usually commence eight to ten weeks prior to the May finals.

In 1977, the Canadian Team Handball Championship was held in Moncton, New Brunswick, and the most successful team at those championships was the Alberta Senior Mens Provincial team, which came out of the competition without a defeat. This same team, with a few additions, continued its success by defeating the United States in the Western Hemisphere zone eliminations in October of 1977, winning the right for Canada to compete at the 1978 World Championships. It was decided that, due to the success of this team, the athletes which made up this team could supply valuable descriptive data in expanding the knowledge and understanding of top competitive Team Handball athletes in Canada. This data could be accumulated to establish general standards for competitive athletes aspiring to reach higher level competition.

According to personal observations and experience, the basic physiological requirements of the sport of Team Handball are:

1) moderately high aerobic power, and
2) high anaerobic capacity.

The basic ability requirements of the sport of Team Handball are:

1) sprinting - the length of a standard court is approximately 40m.
2) jumping - height and distance, (depending on position played).
3) throwing - shot velocity is an important component of most attempts to score.

Basic physical requirements of the sport of Team Handball may determine the position one is most suited to play.

These physical or dimensional entities can be characterized simply by:

1) height
2) weight
3) body composition, i.e. the per cent body fat.

THE PURPOSE

It was the purpose of this study to:

1) Present descriptive data and determine changes in aerobic power as measured by a modified Maksud and Coutts continuous treadmill test to determine maximal oxygen uptake.
2) Present descriptive data and determine changes in anaerobic capacity as measured by a one minute bicycle ergometer test to determine anaerobic capacity.
3) Present descriptive data and determine changes in body composition as measured by the hydrostatic weighing method.
4) Present descriptive data and determine changes in performance as measured by a series of specifically designed performance tests, i.e.
    a) 40 meter sprint, with timed values after 10 meters and 40 meters,
    b) vertical jump,
    c) distance jump, and
    d) shot velocity.
5) Present descriptive data and determine changes in weight as measured by normal weighing procedures.

The presentation of data and determination of changes was done for the period of time from the beginning of the Team Handball season in November to its termination in May.

LIMITATIONS

1) The daily activities of the subjects were not controlled.
2) The study was limited by the extent to which each subject generated maximal effort for each test. It was impossible to completely control the motivational levels during testing sessions.
3) Temperature and humidity in the testing labs were not controlled but assumed to be reasonably constant from one test to the next.
4) Weekly training sessions were not controlled since the subjects were composed of players from four different senior teams in Edmonton.

DELIMITATIONS

1) Only ten subjects, members of the Alberta Provincial Team Handball squad were used.
2) The study was limited to 5 series of tests for each of the physiological parameters and physical peformance parameters outlined in the purpose.

HYPOTHESIS

There is no significant difference at the .05 level of significance for the following,

1) maximal oxygen uptake,

2) anaerobic capacity,
3) per cent body fat,
4) distance jumping,
5) vertical jump,
6) 10m sprint time,
7) 40m sprint time,
8) shot velocity,
9) weight,

at the end of a competitive season of Team Handball when compared to the beginning of the season.

JUSTIFICATION

With the spread of Team Handball from continental Europe, and its increased popularity throughout the world, Canada finds herself faced with internal and external pressures to compete on the competitive World Team Handball scene. Though a leader in North America, and perhaps the Wester Hemisphere, Canada's performance leaves a great deal to be desired when compared to the World Team Handball powers.

This case study involving top competitive Team Handball athletes will provide a source of facts from which direction and understanding of various physiological and performance evaluations can be drawn. The accumulation of knowledge on specific subject matter can provide a tool for guidance of not only functional changes in present and future competitive Team Handball athletes, but also functional changes leading towards a progressive development of the game at the grass roots level.

DEFINITION OF TERMS

aerobic power:	the ability of an individual to take up and use oxygen per unit time during physical work when breathing air.
anaerobic capacity:	the ability of an individual to perform at a high intensity of work and incur the highest possible oxygen debt within one minute.
MVO_2:	a measure of aerobic power. The maximum amount of oxygen an individual is able to take in and utilize during physical work. (measured in ml. per kg. body wt. per min.)
kilopond (kp):	one kp is the force acting on the mass of one kg at normal acceleration of gravity.
kilopond metre (Kpm):	a measure of work on the bicycle ergometer. This is a product of tension setting on the ergometer, the distance travelled by the ergometer wheel in one

	revolution , and the number of pedal revolutions per minute.
wing-backs:	the wing-back positions consist of a left and a right back. When normal offensive team formation is assumed, the wing-backs are responsible mainly for the outside and back area, usually closer to the middle than the wing.
centre-backs:	there is only a possibility of one centre-back and this position is assumed usually in the back area between the left and the right back.
wing:	the wing position consists of a left and a right wing. When normal offensive team formation is assumed, the left and the right wings are responsible mainly for the forwardmost outside areas.
pivot:	there can be either one or two pivots depending on the offensive formation. The pivot is responsible for the area along the 6m line.

All positions are represented diagramatically below in normal offensive positions.

RW: right wing

RWB: right wingback

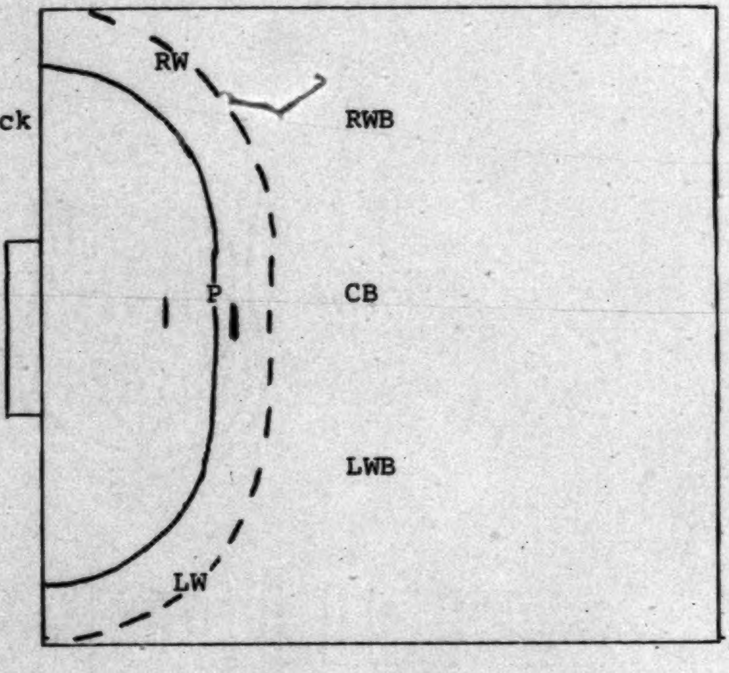
CB: centre back

LWB: left

wingback

LW: left wing

P: pivot



CHAPTER 11

LITERATURE REVIEW

THE USE OF MVO$_2$ AS A MEASURE OF AEROBIC POWER

Investigators for over sixty years have been interested in the determination of maximal oxygen uptake. (Benedict,1913) As early as 1923, Hill and Lupton (1924) in their classical work established that there exists an interindividual variation in maximal oxygen uptake, which is crucial for the ability to perform prolonged muscular work. (Astrand, 1956;Bock, 1968;Herbst, 1928)

According to Hill(1926), maximal oxygen intake is reached when oxygen intake per unit time has attained its maximum and remains constant owing to the limitation of the circulatory and respiratory system. (Mitchell, 1958) Maksud and Coutts, (1971) take this a little further and state that the Max VO$_2$ is a reflection of the combined or synergistic capacity of respiration, circulation and intermediary energy metabolism. When this maximum is reached, a further increase in workload will not elicit any increase in oxygen uptake. This "levelling off" has been used as a criterion for the attainment of a maximal value. (Astrand, 1952;Taylor, 1955) Oxygen requirements, including the maximal oxygen intake, necessitates additional energy to be supplied by means of anaerobic metabolism involving the contraction of an oxygen debt. (Dill, 1962)

Today there is a widespread acceptance and general agreement that maximum oxygen uptake gives an accurate measure of the following: 1) cardiorespiratory health, 2) physical work capacity, 3) maximal aerobic power, and 4) capacity to sustain prolonged heavy muscular work. (Rasch 1974;Astrand, 1970;Drake, 1968;Davies, 1969;Loring, 1956; Taylor, 1955;Balke, 1959;Astrand, 1979;Miyamura, 1972; Maksud, 1971;Anderson, 1966;Cumming, 1967;Mitchell, 1958; Saltin, 1964;Wilmore, 1969;Newton, 1963)

DIRECT TREADMILL VS OTHER METHODS

Many methods for assessing MVO_2 have been developed and recorded in the literature. (Glassford, 1965) Essentially, however, three methods of producing standard work loads have been mainly applied; running on a treadmill, working on a bicycle, and using a step test.

According to Astrand(1970), any test of maximal oxygen uptake should, at least meet the following general requirements:

1) The work must involve large muscle groups.

2) The work load must be measureable and reproduceable.

3) The test conditions must be such that the results are comparable and repeatable.

4) The test must be tolerated by all healthy individuals.

5) The mechanical efficiency (skill) required to perform the test should be as uniform as possible in the population to be tested.

Glassford (1965) working with twenty-four male subjects, ages 17-23, used three direct maximal tests (of which two were treadmill and one bicycle ergometer), and one indirect test (a bicycle ergometer test). It was found that the two treadmill tests yielded significantly higher (8%) mean values than did the direct bicycle tests.

Miyamura (1972) measured the MVO_2 in seventeen students ages 18 - 23 during maximal treadmill and bicycle ergometer exercise. It was found that either with incremental or constant loading, the average values of oxygen intake and cardiac output during treadmill exercise, were higher than the bicycle ergometer exercise.

Hermansen and Saltin (1969) ran maximal tests on fifty-five male subjects ages 19 - 68 years. They obtained an average 7% higher oxygen uptake from the treadmill tests than from the bicycle ergometer. Shephard (1968) repeated testing of the twenty-four subjects and showed that the VO_2

max was greatest on the treadmill, 3.4% smaller in a stepping test and 6.6% smaller during work on a bicycle ergometer. It was recommended that uphill treadmill running be used for laboratory measurements for (VO_2) max.

McArdle (1973) compared Max VO_2 in fifteen male college students by using six discontinuous and continuous bicycle ergometer and treadmill tests. He found that the mean values for Max VO_2 on the bicycle tests averaged from 10.2% to 11.2% below (p .01) the three treadmill tests. It has been demonstrated that the threshold of anaerobic metabolism is lower for work on the bicycle ergometer than on a step or treadmill test. (Katch, 1969;Shephard, 1968)This has been attributed to the particular recruitment of fast and slow twitch fibres, or the relative amount of muscle mass involved in the work performance. (Bailey,1975) There is a greater amount of isometric work in bicycle exercise and greater impairment of muscle blood flow with greater stress on one muscle group (the quadriceps) and less time for relaxation. (Kay, 1969;Newton, 1963)

COMPARISONS OF TREADMILL VARIATIONS

Research has been conducted to determine differences in MVO_2 resulting from varying the treadmill exercise.

1) Uphill Treadmill Running VS. Level Running with Increasing Speed.

Taylor(1955) found that using a constant speed (7mph), and increasing the grade in steps of 2.5% is more satisfactory in eliciting (VO_2) max than using a constant grade and increasing the speed. It was also shown by Taylor that this increase in oxygen consumption, associated with an increase of 2.5% grade (below the max) is approximately 300 cc/min. If, therefore, the oxygen intake at two different grades differed by less than 150 cc/min., or 2.1 cc/kg of body weight per minute. Taylor concluded that a maximal intake had been attained.

2) Treadmill Running VS. Treadmill Walking.

Stamford (1975) studied the (VO_2) max of three different groups of subjects while they performed maximal treadmill tests walking at 3.5 and 4.5 mph, and running at 4.5,5.5,7.0 and 8.5 mph. He found that VO_2 max elicited during walking was independent of speed and less than VO_2 max obtained during running. Best results were obtained when subjects ran at 7.0 mph.

3) Continuous VS. Discontinuous Treadmill Running.

According to McArdle(1973), discontinuous treadmill protocols for determinations of VO_2 max average 60 to 70 minutes. It is often required to have more than one testing session in order for a VO_2 max to be reached. This encumbering time factor creates extreme hardship not only for the subjects but limits, to a great extent, diversified research by consuming a large percentage of the time available for research of this specific nature. In a discontinuous test where more than one session is required, fitness may change while the measurements are being made, causing additional problems. (Shephard, 1968)

Motivations are another extremely important variable, particularily in research which requires maximal effort. From observation it appears that in many cases, motivation is inversely proportional to the time spent on a particular performance. Problems such as these have prompted researchers to develop new treadmill protocols which will bring about desired max VO_2 in a much shorter period of time and in one session.

Shephard (1968) studied twenty-four subjects on various modes of determining VO_2 max including a discontinuous and a continuous uphill treadmill protocol. He found that after loadings were known from discontinuous tests and supplied to the continuous tests, the result was a slightly higher maximum oxygen uptake (average +2.7%) with the continuous test.

McArdle (1973) in his study comparing fifteen male college students by the use of six discontinuous and continuous bicycle ergometer and treadmill tests found there were no differences observed in max VO_2 between the continuous and discontinuous treadmill running tests. From the standpoint of administrative feasibility, McArdle recommended that the continuous treadmill test for obtaining direct measures of max VO_2 be used with large numbers of healthy subjects. McArdle's (1973) protocol required the subjects to run for two minutes at 7 mph at 0% grade, and the treadmill was then elevated 2.5% for each successive two minutes of the run until the subjects could no longer continue.

Maksud and Coutts (1978) tested twenty young adults for the purpose of comparing a single session continuous graded treadmill protocol with the multisession discontinuous graded treadmill procedure described by Taylor (1955) and his co-workers. The treadmill protocols were administered in random order to all subjects and the total experiment for each subject was completed within a two-week time span. Maksud and Coutts found no significant differences in mean VO_2 max between the two test procedures. It was concluded that the continuous test permits reasonably accurate measurements of max VO_2 in group studies.

Upon consideration of the above articles and practical knowledge of testing conditions it becomes obvious that with the laboratory available and when dealing with subjects who are in reasonably good condition, a continuous treadmill protocol is the most efficient procedure to follow. Technological advancement in the development of computerized gas analysing equipment, such as the Beckman Metabolic Cart, has certainly added to the efficiency and subsequent popularity of continuous treadmill protocols when an accurate VO_2 max is desired.

EXPRESSION OF VO_2 MAX IN TERMS OF LBM

A number of modifications have been suggested to more accurately define VO_2 max and its relation to physical fitness. One of these modificatons has been the expression of VO_2 max in terms of lean body mass (LBM).

As a result of improved densitometric research, Buskirk and Taylor (1954), proposed this concept as a refinement of the VO_2 max procedure. In 1956 Van Dobeln suggested that there was no difference in oxygen consumption between men and women on the basis of VO_2 max expressed as a function of LBM. Macnab (1969) provided some very strong evidence contrary to Van Dobeln's conclusion. Macnab demonstrated that men are superior to women in terms of both oxygen consumption and work capacity. Needless to say, a great deal of confusion surrounds the application of this concept with VO_2 max.

Gitin (1974) attempted to clarify some of the confusion with a study involving eighteen subjects of the Staff Non-Commissioned Officers Academy, Camp Lejiune, N.C. The subjects were tested for VO_2 max, body composition, and a number of physical fitness tests including a timed three-mile run, timed bent-knee sit-ups, and pull-ups. The results of the tests indicated that the per cent fat correlated negatively with the performance scores on the fitness tests.

Gitin analysed the equation used to calculate maximal O_2 consumption on the basis of LBM.

VO_2 max = O_2 (litres/min.)/body wt. (kg) - fat (kg)

He concluded that the mathematical removal of fat results in the driving up of the quotient by increasing the numerator (consumes more oxygen) and decreasing the denominator (reduction of weight). The conclusion is obvious that leanness is negatively weighted if fitness is expressed as a function of LBM, opposite to what the results of Gitin's research indicated.

Gitin, in further analysis, advanced that:

> "...to accept that the concept of VO_2 max on the basis of LBM, one must assume:
> a) the excess adipose tissue does not interfere with rapid delivery of oxygenated blood to the metabolically active tissue making up the "Lean Body Mass;" and,
> b) the fat does not consume an appreciable amount of oxygen during maximal exertions."

Studies concerning the effect of excess adipose tissue on blood circulation (Neilson, 1968) and oxygen consumption of adipose tissue during exercise (Ball, 1961; Davidson, 1960;Felig, 1973;Orth, 1960;Vendsalu, 1960) suggests that adipose tissue is more than an inert entity only adding to final body weight and to consider it so is erroneous and leads to erroneous conclusions about fitness.

One must therefore be extremely careful about the use of VO_2 max as a function of LBM particularily in terms of evaluating the ability to do exhausting work.

TRAINING AND VO_2 MAX

It appears that one must be exceedingly careful when attempting to use VO_2 max as an indicator of state of training. The VO_2 max may tell very little about prior training since research indicates that this variable is predominantly determined by heredity. (Astrand, 1970; Davies, 1969;Herrald, 1939) Trainings' greatest effect according to Davies (1969), seems to be a greater co-ordination of the oxidative mechanisms, a decreased accummulation of anaerobic metabolites , and a small increase in endurance time. (Astrand, 1970; Davies, 1969;Girandola, 1973; Karlssen, 1972;Klausen, 1974) Perhaps even a more significant finding has been that endurance time on a bicycle ergometer may be doubled after five weeks of training at 75% of VO_2 max while the VO_2 max is increased only 7%. (Gleser, 1971) Williams (1967) has shown that the main effect of physical training is on the level of oxygen consumption at which anaerobic metabolism, (measured as excess lactate) commences. In his study, Williams (1967) reported that the percentage of VO_2 max, at which anaerobic metabolism commences, increased 16% from 46% to 62% while the VO_2 max increased only 7%. It appears, therefore, that an individual can substantially increase his work before exhaustion, by only increasing his VO_2 max by a small amount.

Davies (1969) defines the term "endurance fitness," as the highest rate of work which can be performed by purely oxidative means without the occurance of anaerobic metabolites (above resting levels), and therefore continued for prolonged periods without undue fatigue.

HYDROSTATIC WEIGHING AND BODY COMPOSITION

According to Keys and Brozek (1953), when considering human energy metabolism, it is essential to distinguish between the primary metabolically active and relatively inactive components of the body. This distinction opened the way for the appraisal of body composition in terms of compartments and subsequent division of the body into the fat and fat free components.

Benke (1942) initiated the use of calculating the amount of body fat from specific gravity determinations. On the basic presupposition that the specific gravity of fat is less than that of other body components and therefore an inverse relationship exists between the fat components and total body density, it was concluded that, by using the principle of Archimedes, a valid measure for estimating fat content was possible.

It must be emphasized at this point, that the method of hydrostatic weighing does not measure body density but rather, gives an estimation of body volume which may be divided by the weight to give the estimate of density.

Rathbun and Pace (1945) followed up the initial momentum generated by Benke and developed a formula for the estimation of per cent human fat on the basis of their studies with animals.

Rathbun and Pace formula:

$$\%\ \text{Fat} = 100\ \frac{5.548}{\text{S.G.}} - 5.044$$

Therefore, an estimate of percent body fat could be made from a measure of the specific gravity of the total body where specific gravity of body fat was assumed to be 0.918 and specific gravity of the fat free component was assumed at 1.10.

Brozek (1949) advanced the concept and in 1953 developed a reference man as a new method for estimating fat content from body density. This reference man was constructed on the basis of determinations obtained from 25 healthy men with a average age of 25 years. The density of the reference man was 1.0629 gm/cc and had a fat content of 14% gross body weight. Changes from this reference man were assumed to involve changes in cellular matter, fat and hydration. (Bergren, 1950) The fat content could then be estimated from the following formula derived from values of the reference man.

$$fb = \frac{4.201}{Db} - 3.813$$

where fb is the total body fat, and

Db is the body density.

Brozek et al. in 1963, replaced the reference man with the reference body. This body was derived from determination on three male cadavers and had a body density of 1.064 with 15.3% fat.

From the reference body, the formula became:

$$fb = \frac{4.570}{Db} - 4.142$$

According to Brozek(1963), the values of this formula, as compared to his previous one, alter the amount of fat corresponding to a given density only insignificantly. The advancement of this formula is that it is based on imperically determined values as opposed to the assumed or hypothetical previous values.

A.) CORRECTION FOR INSPIRATORY AND RESIDUAL VOLUME

Before the true body volume can be obtained, the weight of the water displaced by the air in the lungs and respiratory passages must be subtracted from the apparent weight of the body underwater. The air within the lung's respiratory passages can be divided into two: 1) the inspiratory volume, and 2) the residual volume.

1. Inspiratory Volume

Howell (1962) studied the reliabilities of the inhalation and exhalation techniques during underwater weighing. Reliabilities were reported to be 0.92 and 0.87 respectively. Other researchers have found the exhalation technique to deliver higher reliabilities. (Welch, 1951) It appears that the difference however, is almost insignificant, and most researchers prefer the inhalation technique because it eliminates a great deal of anxiety which accompanies total submersion. (Cournand, 1941;Von Dobeln, 1956)

2. Residual Volume

Among the many methods for determining residual volume, the direct approaches on the most part, involve complex equipment and techniques. The resulting standard error of measurement for these direct methods however, remain at approximately 100 ml. (Cournand

1941;Gibson, 1949;Herrald, 1939;Motley, 1957) As a result of these combined difficulties with direct measures of residual volume, researchers have attempted to further explore the possibilities of various simpler indirect measures. Essentially, three types of indirect procedures have been cited, 1)using an assumed average value for all subjects, (Brozek,1951; Brozek, 1953; Gnaedinger, 1963;Howell, 1962)2)estimating the residual volume from the easily obtained measure of vital capacity, (Kindig, 1968)or 3)estimating the residual volume from other physical characteristics of the subject. (Allen, 1963;Chinn, 1960;Cooper, 1966)(cited from Wilmore)

Wilmore (1969) studied 69 male and 128 female subjects and found that for the majority of the subjects, there was a close agreement between the actual values of density, per cent fat and lean body weight and those obtained through either estimated or a constant residual volume.

B.) RELIABILITIES OF HYDROSTATIC WEIGHING

The reliability of hydrostatic weighing to estimate body density has been very high. (Buskirk,1957; Ikae, 1966;Katch, 1967;Keys, 1953) Durnin (1960)and Keys (1953)reported that the error was less than 0.004 uits and 0.003 units respectively in 90% of the cases that each studied. Gnaedinger (1963) concluded that "underwater weighing is at present considered to be the most reliable method for predicting body composition for human beings."

C.) CORRECTION FOR V.G.I.

Bidell (1956) used a total body plethysomographic technique and an introgastric balloon to determine V.G.I. He found an average V.G.I. of 115 ml. with a range of 0-500 ml. among subjects and a range of 50-300 ml. from day to day test-retest in the same subject. Buskirk (1957) proposed that on the basis of these findings, the value of V.G.I. be incorporated into the calculation of body density as a correction value. Others have reported that a 115 milliliter volume is insignificant and may be neglected without the accuracy of the method being altered. (Godman, 1961;Lim, 1961;Von Dobeln, 1956)

PERFORMANCE

According to Astrand(1970) the individual's performance is the combined result of the co-ordinated exertion and integration of a variety of functions. Astrand categorized these functions as: 1)energy output in aerobic and anaerobic processes, 2)neuromuscular function via strength and technique, and 3)psychological factors including motivation and tactics.

It is one of the purposes of this study to illustrate the effect of changes on some of the easily measureable factors on specific performance indicators. The physiological factors of primary interest deal with the aerobic and anaerobic processes.

We must keep in mind, however, that the competitive sport event is still the classical test of physical performance particularily in a multiphased team sport such as team handball.

Because of the non singular nature of physical performance it is difficult to isolate the significance of a particular factor to the final outcome of performance. It is of primary interest therefore, to determine the implication of changes in component factors of performance and as a result, make possible an increased performance capacity potential.

EFFECT OF TRAINING ON PERFORMANCE

According to Brouha and Hemmingway, training consists of repeated periods of exercise resulting in more economical and precise execution of the recurring maneuvers. Hemmingway (1959) distinguished two distinct training effects.

1) The disciplining of the individual in patterns of movement which are already within his capabilities, so that a specific result will be produced.

2) The development of the resources and capacities of an individual so that he is able to undertake tasks which originally were beyond his capabilities. (Hemmingway, 1959)

Many studies have been done which demonstrate an increased performance after training. (Cooper, 1968;Cureton, 1964;Cureton, 1956;Hammer, 1965;Hemmingway, 1959;Ikae, 1966;Karvonon, 1967;Knehr, 1942;Robinson, 1941;Robinson, 1941)

It can be concluded that with training, any normal individual can improve his working capacity. Astrand (1970) recognizes, however, that outstanding athletic performances are a unique combination of natural endowment (physical and mental) combined with precise development through training. Either one of these factors working in isolation of the other will inevitably prove futile in the generation of outstanding performance. Brouha (1962) states that physical training increases the efficiency to perform any kind of muscular activity provided that workload is at least moderate. The greater the work load an individual trains for, in a specific activity, results in his being more efficient and capable of doing more work of that specific nature. An example of this is finding that VO_2 max scores are generally higher for men who are involved in strenuous prolonged activities such as cross country skiing or running, and lower in sprinters and high jumpers. Hanne (1965) observed this effect on basketball players and cyclists. He explained that the differences in the two groups were the results of the specific effects of training on the development of different qualities in each group. With basketball training, the stress was short and intensive, primarily anaerobic. Periods of work were alternated with rest. As a result, there was a tendancy to develop speed and agility. On the other hand, road racing requires that cyclists endure long work under sustained load. This type of training tends to principally develop aerobic capacities.

DETRAINING

Knehr (1942) states that any regime that is systematically followed will have its most marked results after the first few weeks. Following the initial rapid gains, more intensive training is necessary if continued progress is to be attained.

Cureton (1964) and Brouha (1962) agree that increased work capacity once increased is rapidly lost if training is not maintained. Brouha states that a lay off after intensive training from four to six days, is accompanied by a significant deterioration of fitness. A lay off from seven to ten days after a moderate level of training, on the other hand, results in a very small decline of fitness.

THE SZOGY AND CHEREBETIU ONE MINUTE BICYCLE ERGOMETER TEST

A.) BACKGROUND

The one minute bicycle ergometer test was developed in response to a need for a standard test to determine anaerobic capacity. The parameters measured in the test are: 1)total work performed, and 2)oxygen deficit.

In tests run on two hundred and thirty six top competitive athletes from fifteen different sports branches, the total work performed and the oxygen deficit were found to correlate highly significantly. (Szogy and Cherebetiu, 1974) In the tests it was determined that the anaerobic rate was 74.4%. Szogy and Cherebetiu (1974) concluded that the anaerobic capacity may be estimated from measured values of the total work performed and can be considered a method for measuring the global anaerobic capacity.

In the tests, each subject underwent a one minute maximal performance on a bicycle ergometer. The number of rotations travelled depended on the individual subjects' anaerobic capacity.

The submaximal work load of 5.8 watts/kg body weight was recognized as sufficient for anaerobic metabolism since during the time period of one minute all the energy from the anaerobic processes (i.e.

phosphates and glycogen, rich in energy) are used. (Keys, 1953) At maximum performances of different durations Christensen and Hogberg (1950) determined that the largest oxygen consumption occurs in the first minute. Keul (1967,1969) determined that the highest lactate values are measured after maximal stress of approximately one minute duration. Also, the highest value of oxygen deficit was after maximum stress following a one minute duration. (Gleser, 1971;Hollman, 1963)

In the Szogy and Cherebetiu (1974) test the entire amount of work is the product of the given stress rotation and the reached number of rotations. To determine the oxygen deficit at first, the oxygen need, as a product 2.4 times the entire work output, was calculated whereby the factor 2.4 corresponded to the oxygen need in milliliters for 1 Kpm by an arbitrary rate of effectiveness of 19.5%. Following the establishment of the oxygen intake and general corrections in STPD through subtraction of the oxygen intake at rest, the additional necessary intake of oxygen was determined. The ratio between oxygen deficit and intake was in relation to the anaerobic and aerobic part of energy availability.

This partial indirect method to determine oxygen deficit is preferable since not more than one minute of exercise is needed.

B.) VALIDITY

The analysis of the results shows that of the two hundred and thirty six subjects, the anaerobic part of the energy availability value was between 71.9% and 76.7% with a mean of 74.4%

This value corresponds to values found by other authors. (Hansen, 1967;Lundin, 1971;Wolkow, 1970) The highest values of both coefficients emerged by representatives of those sports which primarily used the lower limbs in their sport. The mean related to body weight, of the entire work load, is 38.1 Kpm/kg body weight. Their value lies above the value of 34.8Kpm/kg body weight which Dranfeld and Millerowicz (1958) estimated at submaximal value to determine anaerobic capacities. The difference was explained by the fact that the values found by Dranfeld and Millerowicz were gained by a hand rotation ergometer. Also the coefficients devised by Dranfeld and Millerowicz are related to untrained persons.

Between the means of the entire work load, the means of the oxygen deficit found by the fifteen groups of athletes, there existed a high significance correlation. ($r = 0.970$ p 0.001)

Szogy and Cherebetiu (1974) assume that the method used here will find a wider area of application. The global capacity is of interest not only for sports, which are primarily anaerobic or mixed (aerobic and anaerobic) processes, but also for those sports which, through aerobic processes are marked by needs for anaerobic supply especially in the first minute of submaximal work or in phases of submaximal workloads or in phases such as the intermediate and final spurts, for example, cycling sports.

CHAPTER 111

METHODS AND PROCEDURES

SUBJECTS

The sample used for the study consisted of ten top competitive Team Handball athletes. The subjects were selected by National Team coaches on the basis of their proficiency to play the sport. Their ages ranged from 20.5 years to 34 years with a mean of 26.7 years.

EXPERIMENTAL PROCEDURE

All athletes were assigned to one of four groups based upon their position which they primarily played while they were competing on the Alberta Provincial team.

These groups were:

1) wing-backs - left and right (n=4)
2) wings - left and right (n=2)
3) pivots (n=2)
4) centre-backs (n=2)

Seven tests were selected, based upon their ability to measure:

a) aerobic power
b) anaerobic capacity
c) body composition
d) sprint speed - for 10 and 40 meters
e) vertical jump
f) distance jump
g) shot velocity

The duration of the study was six months from the beginning of the Team Handball season in November to its termination at the beginning of May. In all, five testing sessions were set up at six week intervals throughout the season. Complete data was obtained on all the subjects before the Team's participation in the Canadian Team Handball Championships in May.

The subjects underwent the following tests at each test series:

1) a modified Maksud and Coutts continuous treadmill test to determine their MVO_2 (aerobic power).
2) the Szogy and Cherebetiu one minute bicycle ergometer test to determine anaerobic capacity.
3) the body densitometry test using the hydrostatic weighing technique to estimate per cent body fat.

4) the specifically designed performance tests to determine abilities in certain specified performance parameters.

CONDITIONS OF TESTING

Subjects were informed in advance of their individual testing times and of the following conditions of testing.

A. Aerobic Power, Anaerobic Capacity, and Performance Tests:

1) Running shoes, shorts and T-shirts were worn to the testing labs and gymnasia.

2) Subjects refrained from eating, smoking or exercising for at least two hours prior to each test. Drinking of alcohol was prohibited for eight hours prior to each test.

3) Subjects participated in a short training and orientation session a week prior to the first testing session to become familiar with each piece of apparatus and its operation.

B. Body Composition Estimates

1) A thin swim suit was allowed to be worn while the densitometry test was being taken.

2) Subjects refrained from eating, or from drinking alcohol for about three hours prior to the test.

ANTHROPOMETRIC DATA

Prior to each testing series, the following data was collected from each subject:

1) height (cm), and
2) weight (kg).

TESTING PROCEDURES

A. Modified Maksud and Coutts Treadmill Test

The subject was positioned on the treadmill and fitted with a two-way Rudolf #2700 breathing valve and mouthpiece. The expiration valve outlet was attached to the Beckman Metabolic Measurement Cart which analysed expired air and printed compiled data at thirty second intervals. As a warm-up to the test, subjects ran for one minute at five miles per hour and 0% grade. After one minute the speed was increased to seven miles per hour at 0% grade. At the end of the second and subsequent minutes, the grade was increased to 2.5% until the subject terminated the run on the basis of subjective exhaustion.

B. Szogy and Cherebetiu one Minute Bicycle Ergometer Test to determine Anaerobic Capacity

For the purpose of warm-up, the subject worked on the bicycle ergometer for one minute at a load of 2.5 kp at ninety revolutions per minute. Following a rest period of one minute the initial test began. The previously determined work load was set on the bicycle ergometer and held constant during the test period for one minute. Work load was determined in the following manner:

if the subject's body weight was more than 80 kg (176.5 lb.), he was given a 5 kp work load. For subjects lighter that 80 kg, the work load was determined by 1 Kpm/rotation/5 kg body weight less than 80 kg. In other words, subjects with body weights between 75 and 80 kg received 29 Kpm/rotation (or 4.89 kp). Those subjects with body weights ranging from 70.1 to 75 kg worked only with 28 Kpm/rotation (4.67 kp). The subjects were told to work during the test minute as hard as possible under the given load in order to reach a maximum number of rotations. In order to make it easier for the subjects to pace themselves, every ten seconds the remaining performance time was announced to the subjects.

C. Hydrostatic Weighing for Determination of Body Composition

A densitometry tank specifically designed for underwater weighing was used. The tank was filled with water to a depth of approximately five feet. An aluminum chair was suspended in the centre of the tank by four cables which were connected to a strain gauge. The strain gauge was suspended from a beam in the ceiling. The chair was submerged to a depth of one and a half feet (from the seat of the chair to the surface of the water). Stress force on the strain gauge was recorded on a Sargent S.R. 100 Recorder. A weighted belt with an underwater weight of 18.08 pounds was used as a standard added weight to prevent flotation and to get a normal range chart reading on the recorder.

Prior to the test, each subject was weighed in air. The subject then entered the tank and was asked to submerge his head completely wetting his hair, rubbing out all air bubbles. Air bubbles were also dislodged from the body and bathing suit. The subject was asked to sit on the chair and place the weighted belt on his lap. When ready, the subject took a maximal inhalation, pinched his nose, and slowly leaned forward until his entire body was submerged. The position was held until a consistent reading was recorded. The subject was then signalled to sit up. Three trials were repeated with the lowest chart reading used for final record. While sitting in the chair, the subject maximally inhaled and while pinching his nose, maximally expired into a vitalometer. The subject repeated this procedure three times with the highest reading recorded as the vital capacity.

D. Forty Meter Sprint Test

A forty meter sprint track was set up to determine sprint times at ten meters and forty meters respectively. One Lafayette Light Emitter (Model 63502) and one

Lafayette Photocell Sensor (Model 62401) was aligned at 0, 10, and 40 meters from the starting point. Leads from each of the Photcell Sensors were connected to two stop clocks (Model 58007) and two clock latches (Model 58027). Each subject was instructed to start with one foot immediately behind the starting line, while the other was no more than one meter back. Any starting stance was allowed. Whenever the subject was ready he started, breaking the beam as he crossed point 0, which started the two clocks. When the subject reached 10 meters, he broke the second beam, which stopped one clock. At 40 meters the second clock was triggered to stop by his passing through the final beam. The 10 meter and 40 meter times were recorded and the clocks reset for the next subject. Each subject was allowed three trials, with the lowest times counting.

E. Vertical Jump Test

Prior to the jumps, each subject's reach was determined in the following manner; while standing flat footed on the floor and holding an official size-weight handball, each subject was asked to reach as high as they possibly could and touch a measured tape, while maintaining a straight wrist and adequate grip on the ball. Height of reach was then recorded as the distance from the floor to the centre of the ball (i.e. centre point of contact with the tape).

For the test jump, the subjects were instructed to allow themselves a three step approach at a nonspecified angle to the basketball backboard. While holding the handball, the subject then made his approach, jumped and reached to touch the backboard at the highest point of the jump. A recorder at the backboard height marked the point of contact and read the height off the measured tape. Subjects were allowed practice time and three attempts, the highest of which was recorded. Vertical jump was then determined by the difference between the jump height and the standing reach height.

F. Distance Jump Test

The distance jump test was specifically designed to simulate a Team Handball wing jump. Each subject was instructed to take a three step approach and while retaining possession of an official size-weight handball, jump along a line taped on the floor. The distance jumped was the measured distance between the most forward contact point of the take-off to the nearest point of the landing. One recorder was situated at each of these areas to specifically mark and measure. The best of three attempts was recorded.

G. Shot Velocity Test

Cinematography was the means by which to determine velocity of a standard three step approach and maximum delivery throw. Prior to the test, the subjects were allowed to warm-up while emphasizing their throwing arm. When the subjects were ready, they were allowed to take two to three practice throws to become familiar with the throwing alley. The practice throws also allowed the camera operator to practice reading the delivery. When the subject was properly prepared and the camera ready, delivery was filmed. A Photo-Sonics Action Master Camera was used in all the sessions. The camera settings were as follows: framerate - 100 frames/second; shutter angle - 30; exposure time - 1/1200; and focus - 2-4-4. Kodak Ektachrome tungsten, 125 ASA film (16mm) (pushed three times in developing) was used.

Film was processed by C.I.T.V. To facilitate the analysis of the film, a Hewlett-Packard 9864A digitizer and 0825A computer was used.

STATISTICAL TREATMENT

A t-test was performed on all the means of all the subjects together, for the beginning and the end of the season to determine if a significant difference at the .05 level of significance, existed for any of the test variables.

The formula used was:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s\ (\bar{X}_1 - \bar{X}_2)}$$

where $S(\overline{X}_1-\overline{X}_2)$ is the symbol for the standard error of the difference between the two means, $\overline{X}_1$ and $\overline{X}_2$.

$$S(\overline{X}_1 - \overline{X}_2) = \sqrt{\frac{\Sigma x_1^2 + x_2^2}{n(n-1)}}$$

$\overline{X}_1$ is the mean score at the beginning of the season.
$\overline{X}_2$ is the mean score at the end of the season.

$x_1 = X - \overline{X}_1$ x_1 is the deviation of X from the mean $(\overline{X}_1)$
$x_2 = X - \overline{X}_2$ x_2 is the deviation of X_2 from the mean $(\overline{X}_2)$

$df = n_1 = n_2 - 2$

t is the ratio of the difference between the sample means to the standard error of this difference

$$t = \frac{\overline{X}_1 - \overline{X}_2}{S(\overline{X}_1 - \overline{X}_2)}$$ - standard error of difference.

CHAPTER 1V

RESULTS AND DISCUSSION

CHARACTERISTICS OF THE SUBJECTS

Ten top competitive male Team Handball players in Alberta were selected because of their success as a team in National and International Team Handball competition. Some characteristics of the subjects are given in Table I.

TABLE I

Characteristics of the Test Subjects

	MEAN	STANDARD DEVIATION	RANGE
AGE (years)	26-27	3.78	20-34
HEIGHT (cm.)	184.5	5.69	173.1-196.2
WEIGHT (kg) (at beginning of season)	83.02	6.26	73.2-93.4

The main intent of this study was to determine if any significant change occurred in the physiological and performance test results, over the course of a season.

It was not the intent of this study to determine the causes precipitating or associated with physiological and performance change.

Comments or suggestions indicating possible reasons for change have been inserted for interest and speculation for possible future studies or for coaching assistance.

Since some of the reported physiological changes appear to be related to the amount and intensity of specific physical activity, these suggestions could prove very helpful to coaches and players of the Alberta Provincial Men's Team in designing pre-season and in-season physical training programs.

COMPARISON OF MAXIMAL OXYGEN UPTAKE RESULTS

Table II illustrates the comparison of Beginning Season and End Season scores. The MVO_2 test results demonstrate a drop in the mean scores. This drop is significant at the .05 level of significance.

Upon examination of Table III and Figure 1 we note that one very obvious drop in MVO_2 occurs between Test 2 and 3. This period of time spans from mid December to the end of January and is responsible for a drop of 4.24 ml/kg min in VO_2 uptake. Both before and after this major drop, until the end of the season, very little change took place.

TABLE II

COMPARISON OF BEGINNING SEASON SCORES TO END OF SEASON SCORES (all subjects combined)

	BEGINNING		END			
VARIABLE	MEAN	S.D.	MEAN	S.D.	T-VALUE	SIGNIFICANCE
Aerobic	55.07	5.41	50.16	4.13	2.19	*
Anaerobic	102.4	5.13	107.5	3.66	1.60	N.S.
% Body Fat	8.26	3.16	9.17	3.95	0.57	N.S.
Distance Jump	153.60	10.82	154.6	9.86	0.22	N.S.
Vertical Jump	27.75	3.21	27.75	2.78	0.0	N.S.
10m Sprint	1.82	0.09	1.83	0.085	0.33	N.S.
40m Sprint	5.38	0.21	5.49	0.22	1.22	N.S.
Shot Velocity	27.11	1.45	27.41	1.48	0.48	N.S.
Weight	182.65	13.78	184.10	13.61	0.24	N.S.

* Significant at the .05 level of significance

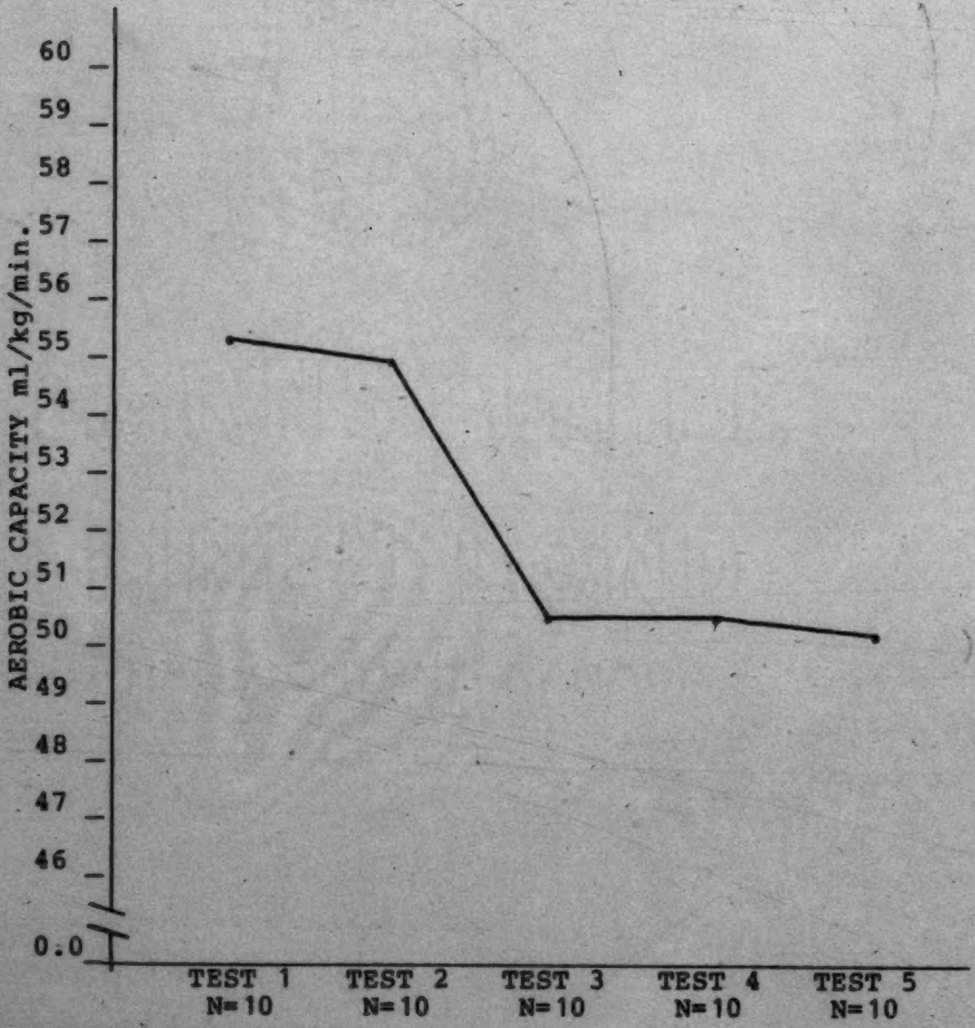
TABLE III

AEROBIC TEST RESULTS (ml/kg min.)

SUBJECTS	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	$\bar{X}$	S.D.
01 - VB	52.2	49.1	50.2	49.3	47.7	49.7	1.66
02 - GB	48.8	54.7	48.3	44.8	48.8	49.08	3.56
03 - RG	57.9	57.7	54.3	52.9	52.9	55.14	2.50
04 - EJ	50.7	48.1	46.7	47.4	47.2	48.02	1.58
05 - TK	52.3	51.2	46.15	45.8	41.4	47.36	4.44
06 - RL	54.3	56.3	53.0	53.45	55.0	54.4	1.33
07 - CP	64.2	60.2	57.4	54.6	52.5	57.78	4.62
08 - ST	62.9	60.4	50.7	55.95	54.4	56.86	4.85
09 - GW	57.7	55.4	49.3	53.8	52.4	53.72	3.16
10 - RW	49.7	56.1	50.8	49.8	49.34	51.14	2.83
$\bar{X}$	55.07	54.92	50.68	50.77	50.16		
S.D.	5.41	4.26	3.47	3.89	4.13		

FIGURE 1

COMPARISON OF AEROBIC TEST MEANS



This phenomenon appears to be the result of a tremendous drop-off in activity during the Christmas break. Usually games and practices cease by mid December and do not start again until the second week in January. The month layoff appears to have had a dramatic effect on aerobic fitness. The drop off in MVO_2 may have been accentuated by the relatively high level of MVO_2 demonstrated by the subjects in test 1 and 2. This level can be attributed to the very intensive training program in which the subjects were involved in preparation for the World Cup Zone eliminations which took place in October against the United States.

Nonetheless, it may be advisable for coaches and athletes to note the potential results of the Christmas layoff and embark on an aerobic fitness maintenance program during this period of time.

COMPARISON OF ANAEROBIC TEST RESULTS

Table II illustrates an increase in the Anaerobic Test results from the beginning to the end of the Team Handball season. This increase is not significant at the .05 level of significance.

Examination of Table IV and Figure 2 reveals that the anaerobic test results behave somewhat differently from the aerobic results. After a very sharp increase between Test I and II, a sharp decrease occurs. From the end of January to the end of the season a more gradual increase occurs.

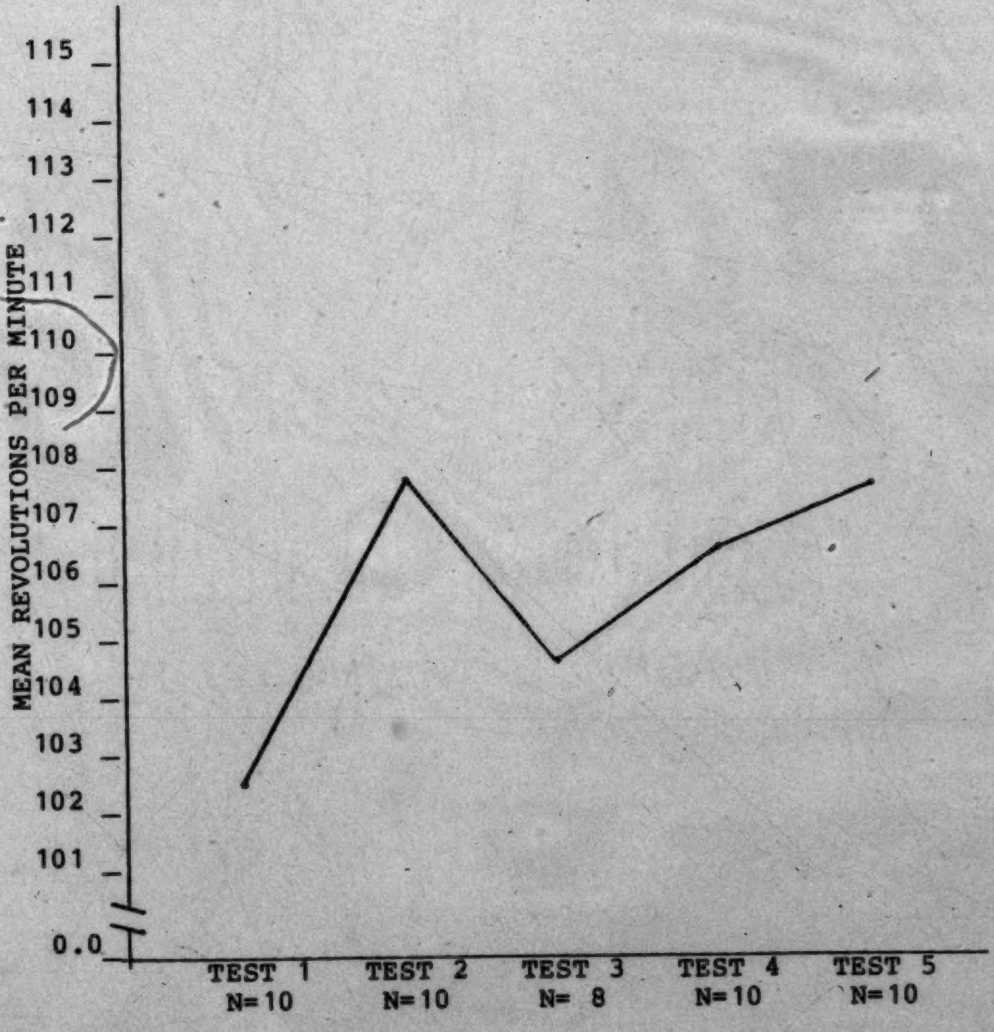
TABLE IV

ANAEROBIC TEST RESULTS (revolutions)

SUBJECTS	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	$\bar{X}$	S.D.
01 - VB	98	104	101	106	106.5	103.1	3.58
02 - GB	98	102	98	94	103.5	99.1	3.75
03 - RG	103	108	108	109.5	108.5	107.4	2.53
04 - EJ	110	110	102	104	106	106.4	3.58
05 - TK	100	103	108.5	112	112	106.7	4.34
06 - RL	103	113	110	107.5	111	108.9	3.85
07 - CP	104	106	108.5	114	109	108.3	3.77
08 - ST	112	118	absent	112.5	110.5	113.5	3.28
09 - GW	98	100	absent	98	100	99	1.15
10 - RW	98	114	101	106.5	118	105.5	6.24
$\bar{X}$	102.4	107.8	104.6	106.4	107.5		
S.D.	5.13	5.87	4.59	6.39	3.66		

FIGURE 2

COMPARISON OF ANAEROBIC TEST MEANS



The reason for the first increase is difficult to explain, but it is the author's speculation that subjects were hesitant to provide a 100% effort in the anaerobic test until the second series.

Differences in Test 2 and 3 can probably be attributed to the Christmas layoff.

The consistent rise from Test 4 and 5 perhaps illustrates the anaerobic nature of the game of Team Handball. In practicing and playing the sport, it appears that the anaerobic component is more greatly stressed than the aerobic component, thus bringing about a training effect.

Again, players and coaches would do well to consider some activities during the Christmas break to offset the drop in anaerobic capacity.

COMPARISON OF PER CENT BODY FAT RESULTS

Table II illustrates that there is a slight increase in the per cent body fat between the beginning of the Team Handball season and the end. This increase is statistically not significant at the .05 level. Figure 3 and Table V demonstrate that this increase is gradual. The sharpest increase, as one might expect, occurs during the Christmas layoff period, with consistent but slight declines as activities increase toward the end of the season. It might be interesting to note that the final per cent body fat mean does not reach the beginning season low.

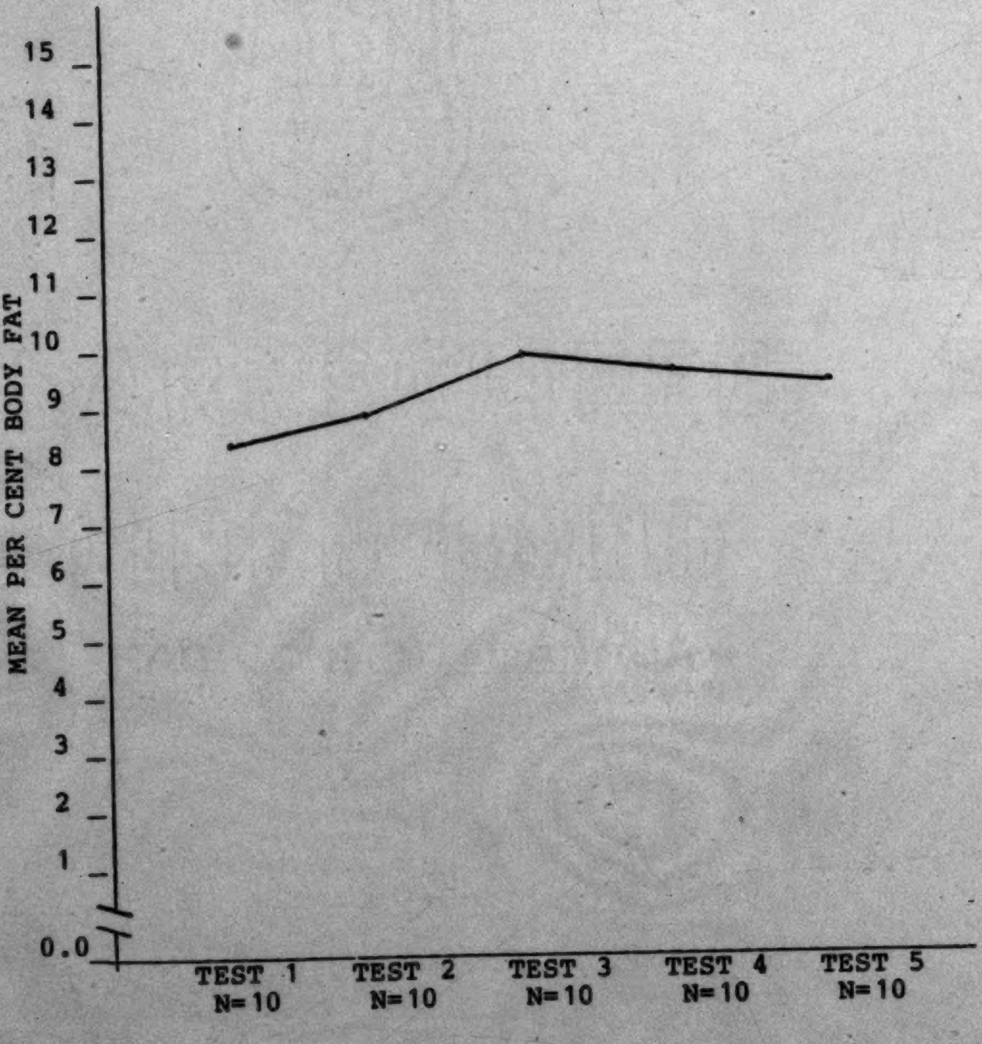
TABLE V

BODY COMPOSITION (% body fat)

SUBJECTS	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	$\overline{X}$	S.D.
01 - VB	5.1	4.6	6.26	5.7	7.1	5.75	0.98
02 - GB	6.45	8.43	12.06	9.1	9.34	9.07	2.01
03 - RG	3.99	6.53	3.95	5.5	4.03	4.8	1.17
04 - EJ	6.88	6.73	6.57	8.36	7.3	7.17	0.72
05 - TK	14.1	15.23	16.36	13.5	17.7	15.38	1.72
06 - RL	9.98	9.65	9.89	11.27	7.65	9.49	1.32
07 - CP	8.24	8.43	8.75	7.25	6.75	7.88	0.85
08 - ST	6.8	4.98	8.75	9.26	8.8	7.72	1.80
09 - GW	9.6	10.4	9.65	10.36	8.85	9.77	0.64
10 - RW	12.46	13.82	15.51	15.05	14.14	14.20	1.18
$\overline{X}$	8.26	8.88	9.78	9.54	9.17		
S.D.	3.16	3.52	3.95	3.12	3.95		

FIGURE 3

COMPARISON OF % BODY FAT MEANS



COMPARISON OF DISTANCE JUMP RESULTS

Table II indicates that there is no significant difference between distance jump scores at the beginning of the season when compared to the scores at the end of the season. From Table VI and Figure 4, it can be seen that there is no apparent pattern to the results through the season. Scores range from a mean 151.8 cm. to 154.6 cm. This difference may be attributed to experimental error and/or individual motivation factors during the performance of this test.

COMPARISON OF VERTICAL JUMP TEST RESULTS

Table II illustrates that there is no significant difference at the .05 level of significance between the mean of the vertical jump test at the beginning of the season and the mean of the vertical jumps at the end of the season.

Examination of the seasonal picture as presented in Table VII and Figure 5 reveals some minor changes particularily involving Test 4. There appears to be no apparent explanation for this dip in the mean. It is speculated that a combination of motivational factors and recorder error may have been responsible.

COMPARISON OF 10M SPRINT TEST RESULTS

Table II reveals that the difference between the means at the beginning of the season when compared to the end is not significant at the .05 level.

TABLE VI

DISTANCE JUMP TEST RESULTS (centimeters)

SUBJECTS	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	$\bar{X}$	S.D.
01 - VB	353	353	368	366	360.5	359.1	5.9
02 - GB	376	391	374.5	345.5	385	374.4	17.5
03 - RG	432	4042	439.5	421.5	428	425.0	13.43
04 - EJ	411.5	396	401	absent	416.5	406.2	9.40
05 - TK	386	393.5	420.5	absent	399	399.6	14.59
06 - RL	376.5	366	377	373.5	372	374.9	2.07
07 - CP	363	358	371	371	363	365.2	5.69
08 - ST	432	437	absent	439.5	429	434.4	4.75
09 - GW	373.5	360.5	absent	368	385	371.7	10.32
10 - RW	399	396	406	401	388.5	398.1	6.48
$\bar{X}$	390.2	385.5	394.06	385.75	393.65		
S.D.	27.6	26.09	27.06	31.83	25.06		

FIGURE 4

COMPARISON OF DISTANCE JUMP TEST MEANS

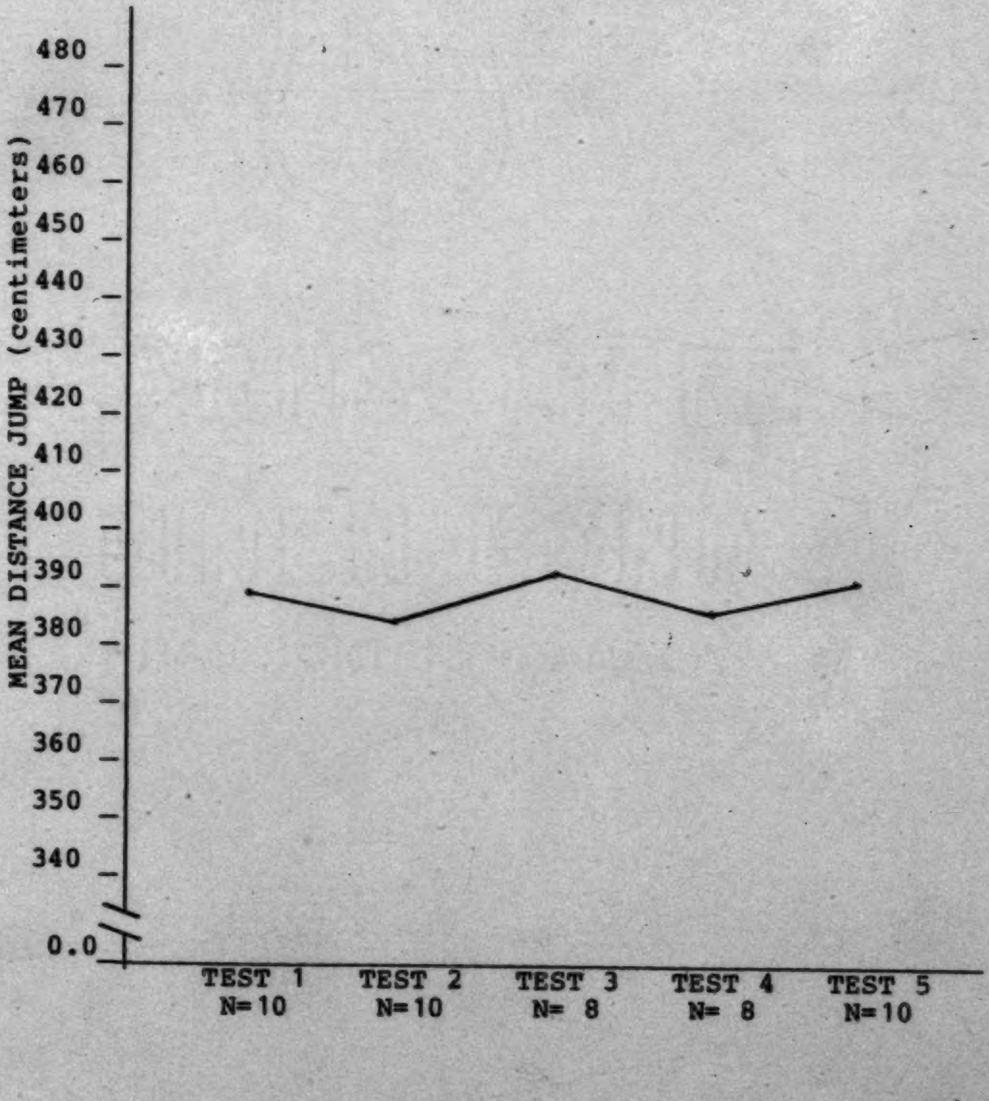


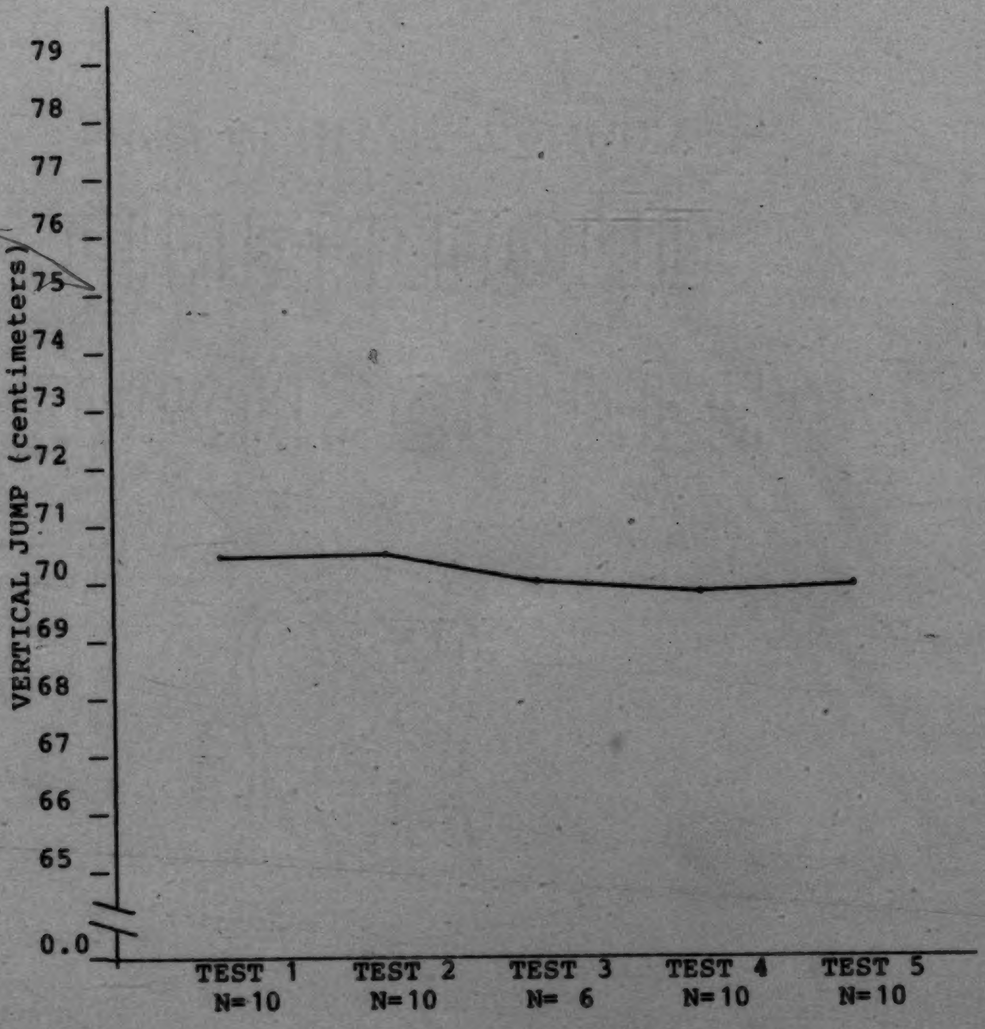
TABLE VII

VERTICAL JUMP TEST RESULTS (centimeters)

SUBJECTS	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	$\bar{X}$	S.D.
01 - VB	67.5	64.8	68.6	66.0	66.0	66.0	1.65
02 - GB	59.5	65.4	62.9	59.7	63.5	62.0	2.49
03 - RG	77.5	76.2	76.2	74.9	76.2	76.0	0.89
04 - EJ	76.0	75.6	absent	73.7	74.9	75.0	1.49
05 - TK	62.0	57.7	absent	58.5	61.0	60.0	1.65
06 - RL	68.5	66.0	66.0	65.0	66.0	66.0	1.40
07 - CP	68.5	72.4	73.7	69.9	72.5	71.0	2.08
08 - ST	87.5	85.7	absent	81.9	85.0	85.0	2.39
09 - GW	71.0	69.9	absent	64.8	70.0	69.0	2.82
10 - RW	66.0	68.0	71.0	64.8	70.0	68.0	2.62
$\bar{X}$	70.5	70.4	69.8	67.8	70.5		
S.D.	8.2	7.5	4.9	7.24	7.1		

FIGURE 5

COMPARISON OF VERTICAL JUMP MEANS



It is interesting to note that from Figure 6 and Table VIII the slowest mean recorded was for Test 3. Any conclusions here would merely be speculation.

COMPARISON OF 40M SPRINT TEST

According to Table II there is no significant difference at the .05 level between means recorded at the beginning and at the end of the Team Handball Season. Table IX and Figure 7 demonstrate a constant slowing of the 40m sprint times to Test 4 and then a levelling off.

The only test result pattern which is similar to these results are the aerobic results, but there are no reasons for any connection and the author concludes that if there is any correlation, then it would more than likely be coincidental.

COMPARISON OF SHOT VELOCITY RESULTS

Table II reveals that there is no significant difference at the .05 level of significance between means for shot velocity at the beginning of the season when compared to the end.

Figure 8 and Table X illustrate that the seasonal variations do not follow any pattern. Contrary to other tests, the best means were recorded during Test 3, but this result was not significant. Variations may be explained as being attributed to changes in individual motivation and experimental error.

TABLE VIII

10m SPRINT TEST RESULTS

SUBJECTS	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	$\bar{X}$	S.D.
01 - VB	2.00	2.00	1.99	1.98	1.98	1.99	0.01
02 - GB	1.85	1.79	1.90	1.80	1.80	1.83	0.05
03 - RG	1.74	1.76	1.75	1.75	1.75	1.75	0.01
04 - EJ	1.72	1.71	1.79	1.72	1.73	1.73	0.03
05 - TK	1.95	1.89	1.96	1.98	absent	1.95	0.04
06 - RL	1.80	1.82	1.78	1.75	1.85	1.80	0.04
07 - CP	1.79	1.92	1.88	1.79	1.85	1.85	0.06
08 - ST	1.74	1.71	absent	1.76	1.80	1.75	0.04
09 - GW	1.84	1.89	absent	1.92	1.88	1.88	0.03
10 - RW	1.78	1.81	1.80	1.78	absent	1.80	0.02
$\bar{X}$	1.82	1.83	1.86	1.82	1.83		
S.D.	0.09	0.09	0.09	0.1	0.085		

FIGURE 6

COMPARISON OF 10 METER SPRINT TEST MEANS

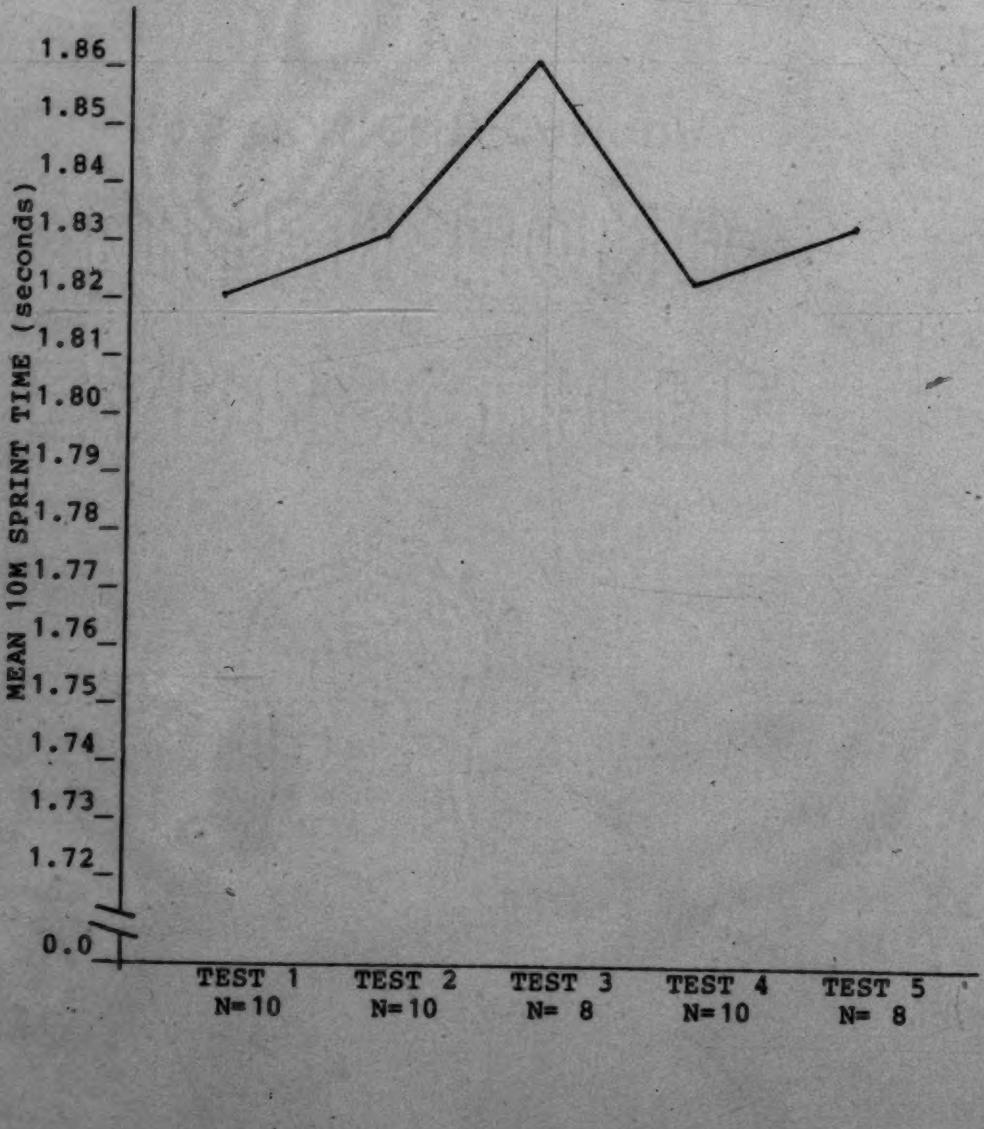


TABLE IX

40m SPRINT TEST RESULTS

SUBJECTS	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	$\bar{X}$	S.D.
01 - VB	5.84	5.74	5.79	5.81	5.82	5.80	0.04
02 - GB	5.38	5.34	5.47	5.50	5.45	5.43	0.07
03 - RG	5.26	5.22	5.25	5.32	5.31	5.27	0.04
04 - EJ	5.14	5.06	5.17	5.26	5.21	5.17	0.08
05 - TK	5.55	5.50	5.60	5.66	absent	5.58	0.07
06 - RL	5.38	5.47	5.39	5.56	5.56	5.47	0.09
07 - CP	5.35	5.60	5.53	5.57	5.67	5.54	0.12
08 - ST	5.09	5.05	absent	5.14	5.23	5.13	0.08
09 - GW	5.46	5.53	absent	5.68	5.40	5.58	0.10
10 - RW	5.39	5.42	5.44	5.45	absent	5.43	0.03
$\bar{X}$	5.38	5.39	5.46	5.50	5.49		
S.D.	0.21	0.23	0.20	0.21	0.22		

FIGURE 7

COMPARISON OF 40 METER SPRINT TEST MEANS

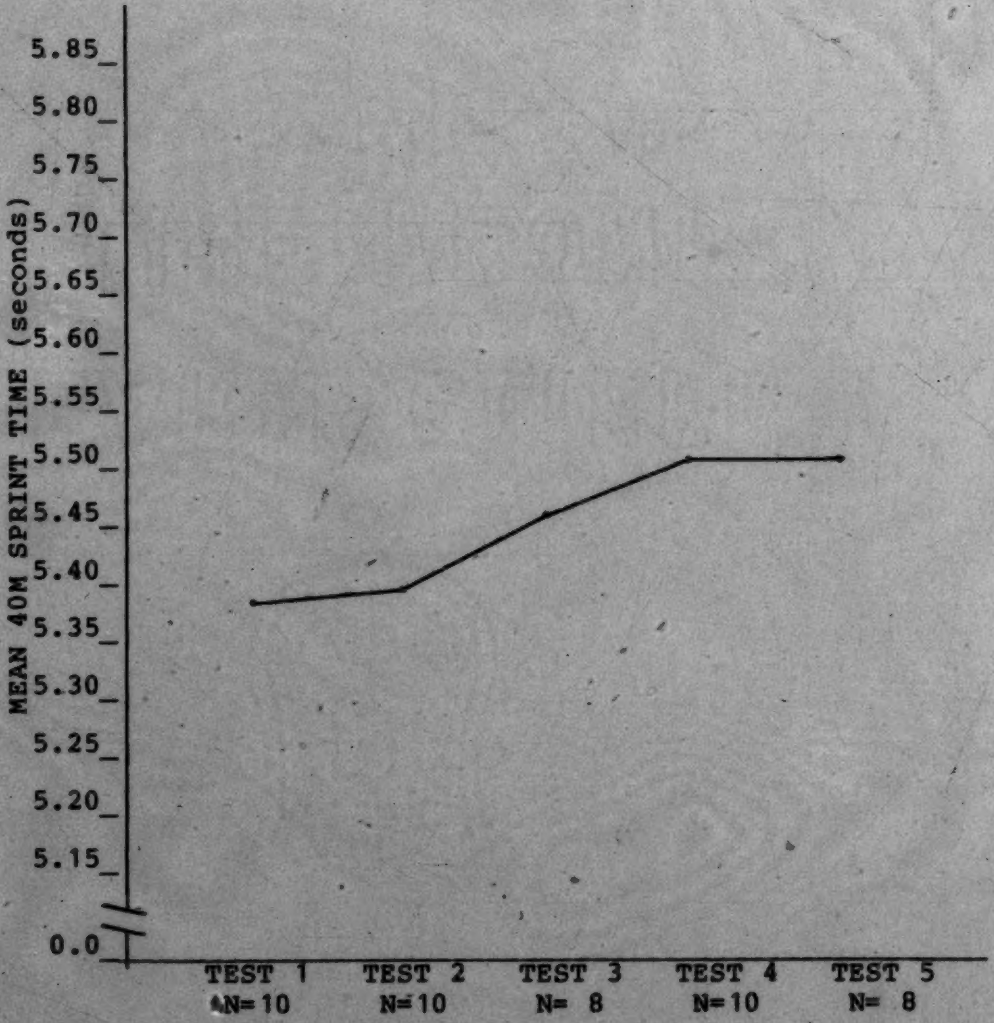


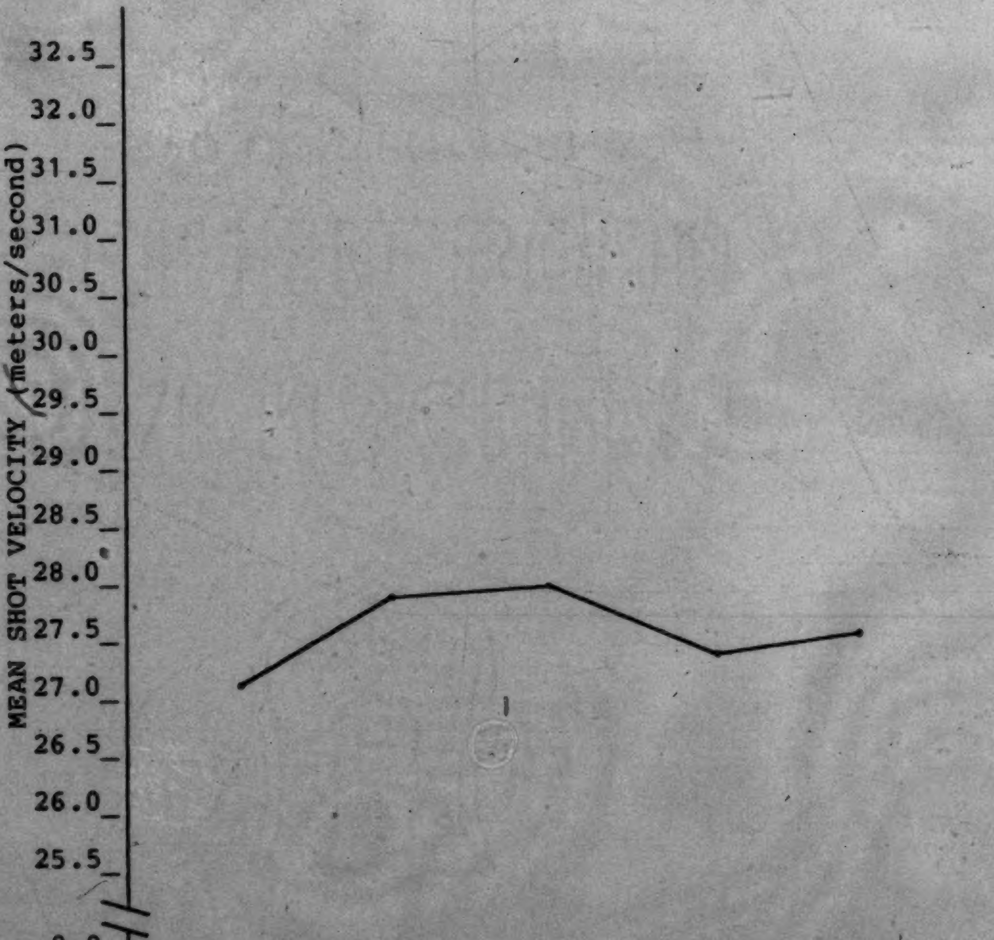
TABLE X

SHOT VELOCITY TEST RESULTS m/sec.

SUBJECTS	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	$\bar{X}$	S.D.
01 - VB	26.51	27.88	27.84	26.64	absent	26.97	0.62
02 - GB	30.16	30.48	30.99	30.92	30.25	30.56	0.38
03 - RG	27.04	28.09	27.97	27.38	28.09	27.71	0.48
04 - EJ	26.68	26.54	26.95	26.59	26.28	26.61	0.25
05 - TK	27.80	28.57	28.51	28.14	29.30	28.26	0.31
06 - RL	27.49	28.35	28.96	27.89	28.27	28.19	0.55
07 - CP	26.80	27.43	28.00	26.98	26.80	27.20	0.52
08 - ST	27.80	28.78	absent	27.10	27.20	27.72	0.77
09 - GW	24.39	26.30	absent	25.75	25.80	25.56	0.82
10 - RW	26.40	26.14	25.68	25.80	25.64	25.93	0.33
$\bar{X}$	27.11	27.86	27.99	27.32	27.41		
S.D.	1.45	1.33	1.6	1.49	1.48		

FIGURE 8

COMPARISON OF SHOT VELOCITY MEANS



COMPARISON OF BODY WEIGHT

Table II indicates that there is no significant change at the .05 level in mean weights between the beginning and the end of the season. Table XI and Figure 9 illustrate a slight rise from the beginning to mid March, then a drop toward the beginning of May. This seems to follow the general trend in activity pattern during the season and although these changes are fairly consistent, their implication in performance cannot be verified in this study.

It is interesting to note that weight changes should normally follow changes in per cent body fat. Upon analysis of Table V and Figure 3, this is generally the case except in Test 4 where the weight increased from Test III while the per cent body fat decreased slightly. This difference, however, is very minor and well within the bounds of experimental error.

PROFILES ACCORDING TO POSITION

The remainder of this chapter will deal with a presentation of descriptive data on the subjects in accordance to the position they primarily played on the Alberta Senior Men's Team Handball Team.

Since the number of each group was very small, no attempts were made to establish profile norms for the positions.

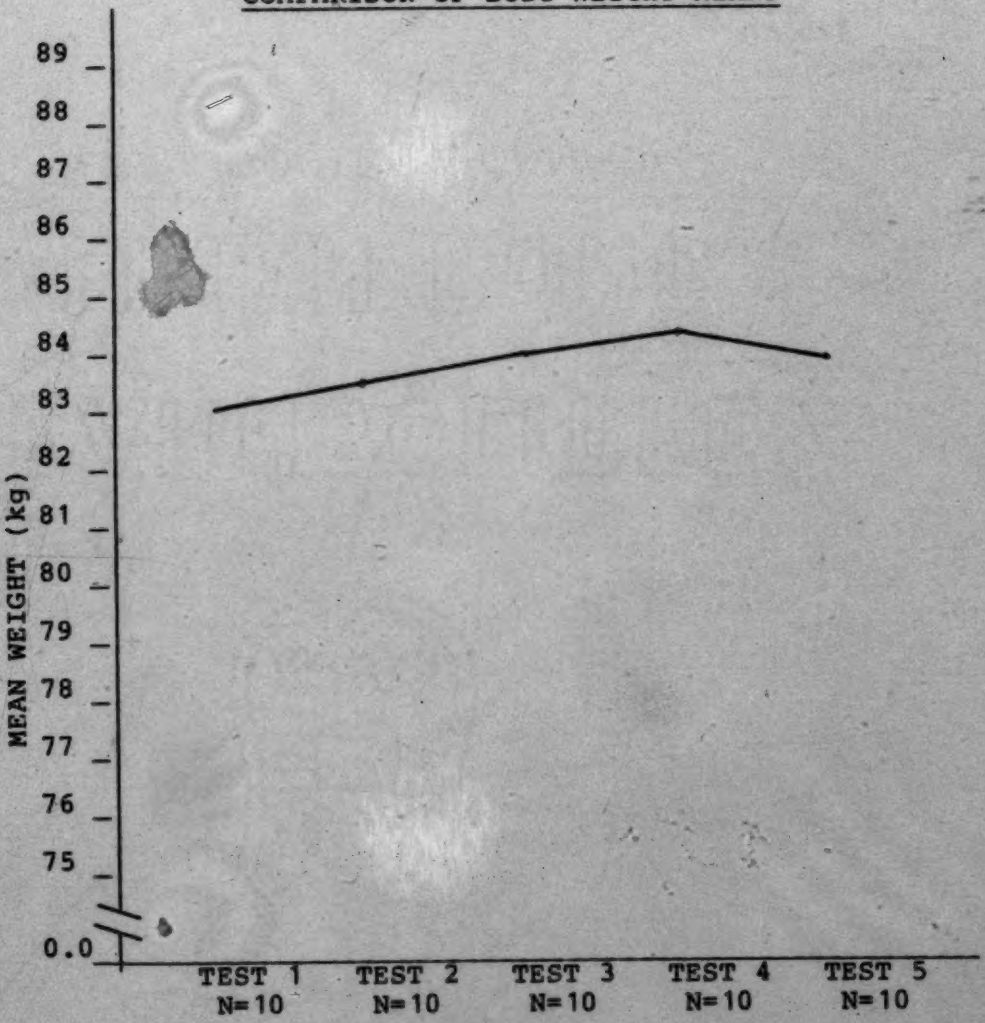
TABLE XI

BODY WEIGHTS (kg)

SUBJECTS	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	$\bar{X}$	S.D.
01 - VB	84.3	84.1	93.9	84.7	81.4	83.7	1.32
02 - GB	91.4	90.9	95.	95.	94.3	93.0	1.95
03 - RG	73.2	73.2	74.1	75.9	75.0	74.3	1.19
04 - EJ	75.7	75.9	77.1	75.4	75.9	76.1	.49
05 - TK	93.4	94.1	94.1	93.2	94.6	93.9	0.55
06 - RL	85.2	85.5	85.7	86.4	83.0	84.1	1.29
07 - CP	83.6	83.9	83.6	82.3	82.9	83.2	0.69
08 - ST	81.4	81.8	81.8	84.1	83.9	82.6	1.28
09 - GW	79.1	80.5	80.9	82.3	82.3	81.0	1.34
10 - RW	83.0	83.6	84.9	85.5	85.7	84.4	1.10
$\bar{X}$	83.02	83.4	84.1	84.5	83.7	83.8	
S.D.	6.5	6.2	6.7	6.21	6.2	0.55	

FIGURE 9

COMPARISON OF BODY WEIGHT MEANS



It may be very interesting however, to see how physical and performance tests indicate trends and characteristics in certain positions when compared to others.

Responsibilities and roles vary from one position to another. These differing roles and responsibilities place specific physical, physiological and performance requirements on an athlete in order that he meet and fulfill the task of the position he plays.

Performance requirements become more acute at the top competitive level and the need to match the athlete with the position becomes an important coaching decision.

Through the results of this study of top competitive Team Handball athletes, perhaps we can gain some fundamental understanding of why certain players were selected for their position and what special skills they have compared to others in other positions.

The 1977 Alberta Provincial Senior Men's Team Handball Team was divided into four profile groups according to the position to which they were selected.

These groups were:

1) Wing Backs n=4

Subjects

02 - GB

05 - TK

06 - RL

07 - CP

2) Centre Backs n=2

Subjects

08 - ST

09 - GW

3) Wings n=2

Subjects

03 - RG

04 - EJ

4) Pivots n=2

Subjects

01 - VB

10 - RW

SUMMARY CHART OF DOMINANT CHARACTERISTICS FROM A COMPARISON OF TEST MEANS ACCORDING TO POSITION (from Figures 10-19 and Table XII-XIX)

WING BACK	CENTRE BACK	WINGS	PIVOT
-tallest and heaviest. -highest per cent body fat. -lowest vertical jump. -highest shot velocity.	-highest aerobic power. -highest vertical jump.	-shortest & lightest. -highest anaerobic capacity. -lowest per cent body fat. -greatest mean distance jump. -fastest 10m sprint time. -fastest 40m. sprint time.	-height same as wings but second heaviest (general description-short and stocky) -lowest aerobic power and anaerobic capacity. -slowest 10m sprint time. -slowest 40m sprint time. -slowest shot velocity.

DISCUSSIONS OF DOMINANT CHARACTERISTICS

WING BACKS

From the above summary we can see some very distinct and meaningful characteristics.

Wing backs are the primary power shooters on the team. Their shooting takes place from the greatest distance from the goal and usually over defensive players. It is therefore not surprising that they are the tallest and hardest shooters on the team. It is a bit surprising that they rank poorly in the vertical jump tests since a high vertical jump would certainly be an advantage in obtaining a clear shot at goal over the defensive players.

CENTRE BACKS

The centre back players are usually the leaders (or quarterbacks)(Level II, Pg.48) on the team and must primarily be the technical and tactical experts. Their primary characteristics should centre around quick thinking, ball control, and timing. Any positive physiological or performance characteristics held by the centre backs will certainly be an asset, but the main responsibility areas of the centre backs are psychological and techno-tactical. These areas were not manifest in the tests of this study.

WINGS

Wings specialize in the following:

1) fast breaks, and

2) scoring from bad angles.

It is very much an asset for the wing to be smaller, quick and have an excellent distance jump. These are the characteristics most dominantly displayed by the wings in the tests and this is certainly not surprising.

PIVOTS

The primary responsibility of the stationary pivot player it to set "picks" and "screens" and be able to shoot from the 6m line. In order to confine defensive players and perform his responsibilities, the pivot must physically be a strong and sturdy player. This type of a player is not the type of player who would be good for fast breaking. The ideal pivot, however, should be mobile, have an excellent set of hands, and be almost acrobatic in order to be a scoring threat from the 6m line. (Level II PG.48)

Since the pivot plays primarily on the 6m line, he does not require a hard shot or ability to jump well. It is therefore not surprising that the pivots did not score well on the tests.

CHAPTER V

SUMMARY AND CONCLUSIONS

The main purpose of this study was to examine changes in physiological and performance characteristics of top competitive Team Handball players in Alberta. Characteristics examined were height, weight, aerobic power, anaerobic capacity, per cent body fat, distance jump, vertical jump, 10 meter sprint times, 40 meter sprint times, and shot velocity.

Descriptive data was presented and changes in characteristic means were determined over the course of a competitive Team Handball season.

Descriptive data was also presented relative to characteristics common to particular positions.

Ten top competitive Team Handball players, all members of Albertas' Provincial Team, participated in this study. This team won the 1977 Canadian Team Handball Championships and also won the Western Hemisphere World Cup Eliminations, earning Canada the right to participate in the 1978 World Cup.

The subjects were tested five times, on all the variables, every six weeks throughout the competitive Team Handball season.

Test data was charted and graphed for descriptive purposes.

A t-test was performed on all the means of all the subjects together, for the beginning and the end of the season to determine if a significant difference, at the .05 level of confidence, existed.

CONCLUSIONS

There was a significant difference at the .05 level of significance between the beginning and the end of the season means for the aerobic power variable. No significant difference was found for any of the other variables.

The Alberta Provincial Senior Mens Team Handball Team decreased in aerobic fitness over the competitive season as measured by MVO_2.

RECOMMENDATIONS

It was felt that with a greater number of subjects in each position, an attempt could be made to establish physical, physiological and performance standards for each position.

It was felt that the process of getting 10 athletes together for 7 tests, 5 different times during a 6 month period was extremely difficult. This process is not recommended.

Muscle biopsis or blood lactate analysis would have provided more conclusive results in determining oxygen debt.

A more in depth analysis could be done to determine the per cent of energy supply from aerobic and anaerobic energy systems.

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APPENDIX

FIGURE 10

COMPARISON OF HEIGHT MEANS BY POSITION

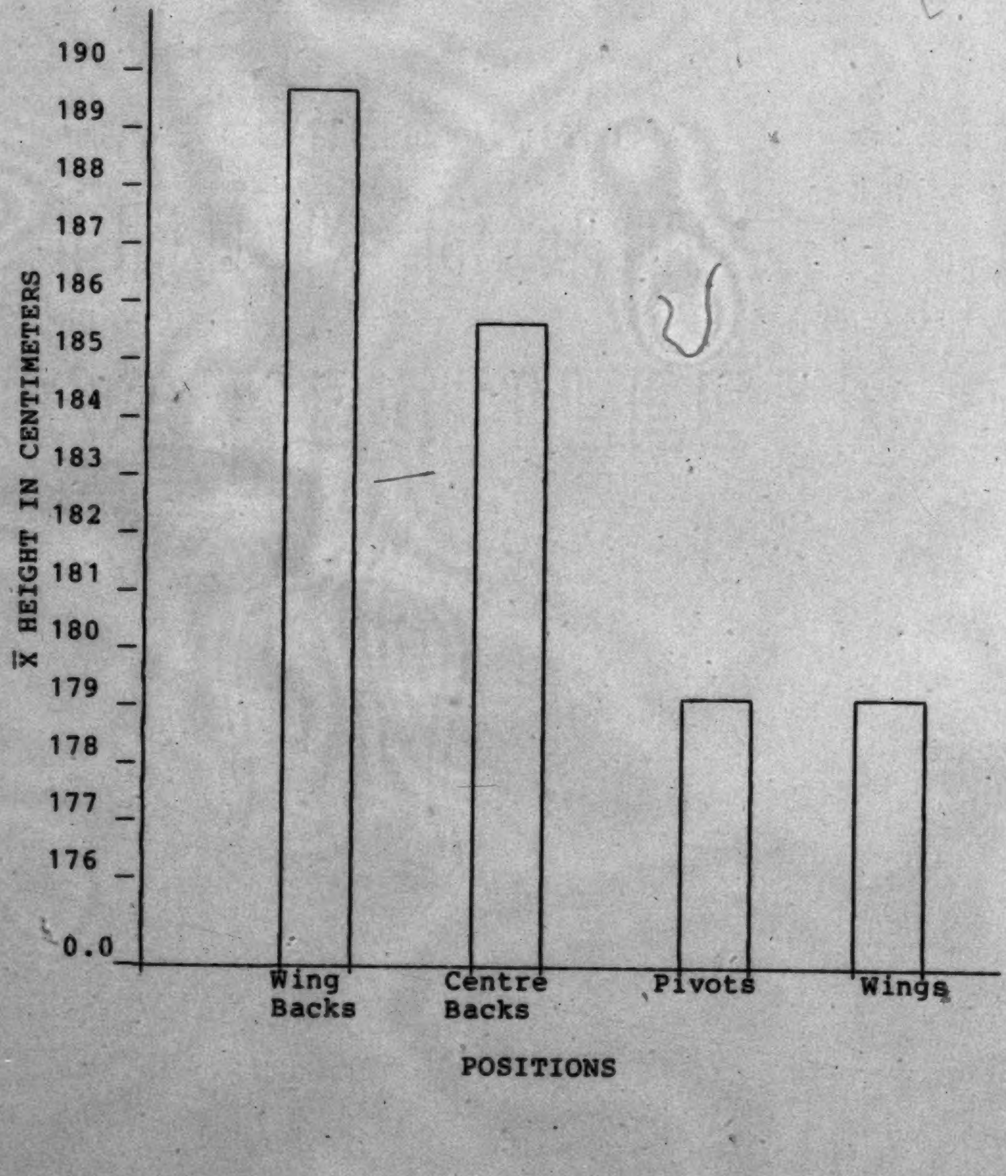


FIGURE 11

COMPARISON OF WEIGHT MEANS BY POSITION

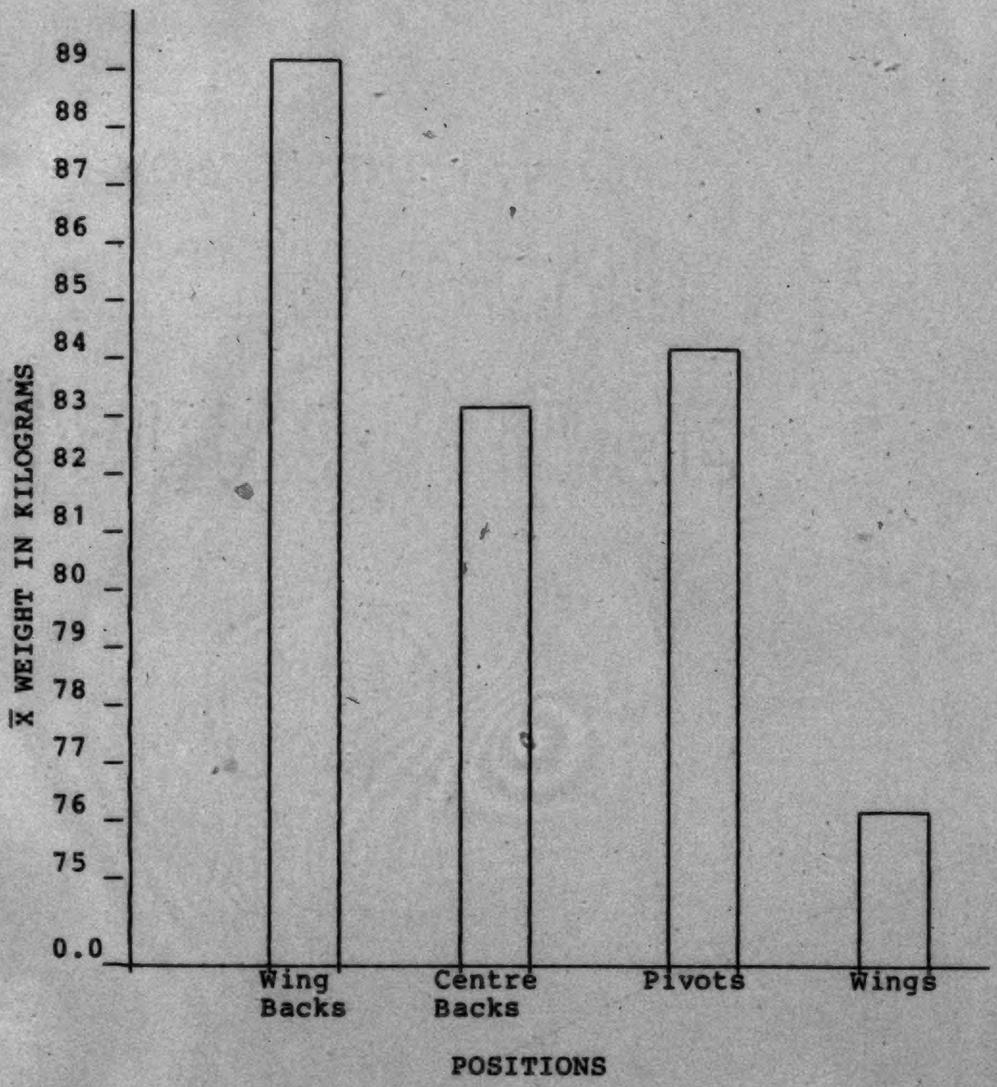


FIGURE 12

COMPARISON OF MEAN AEROBIC POWER BY POSITION

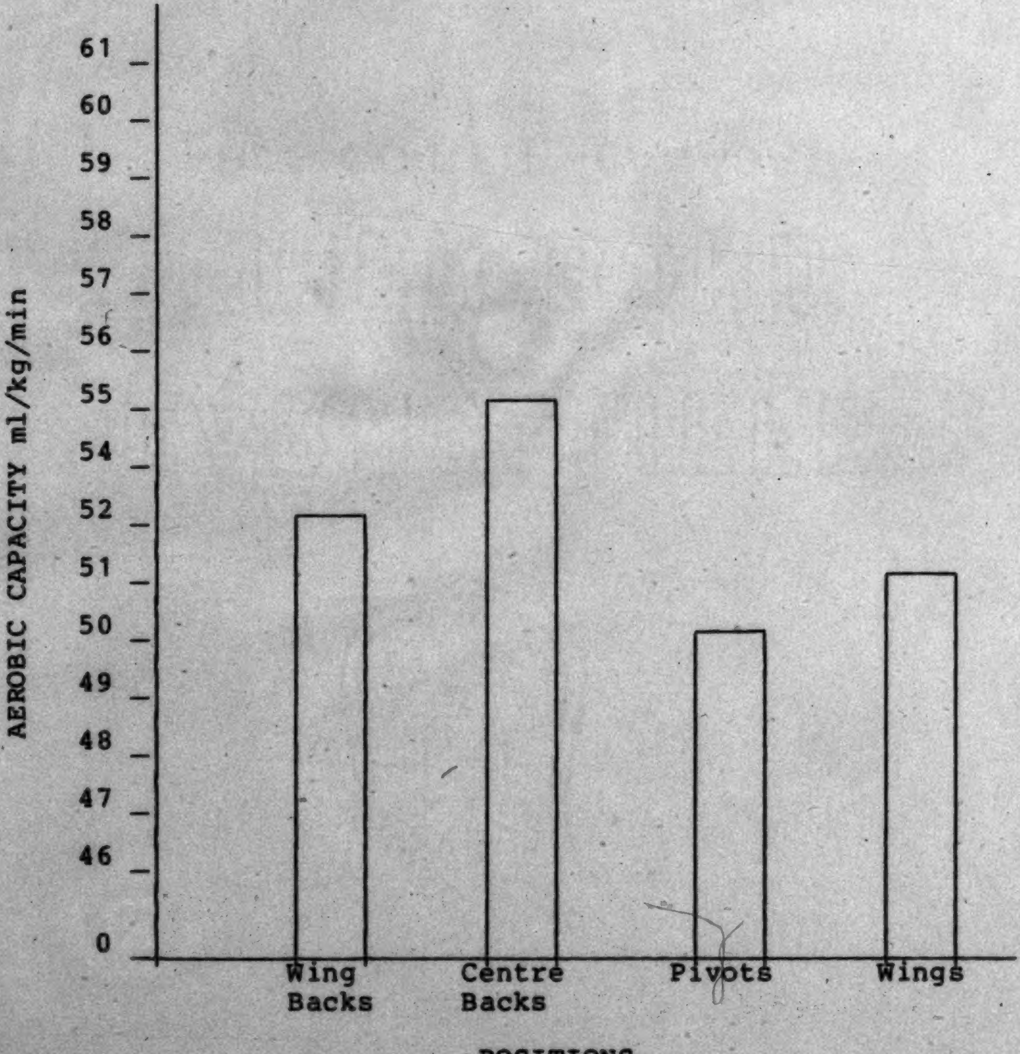
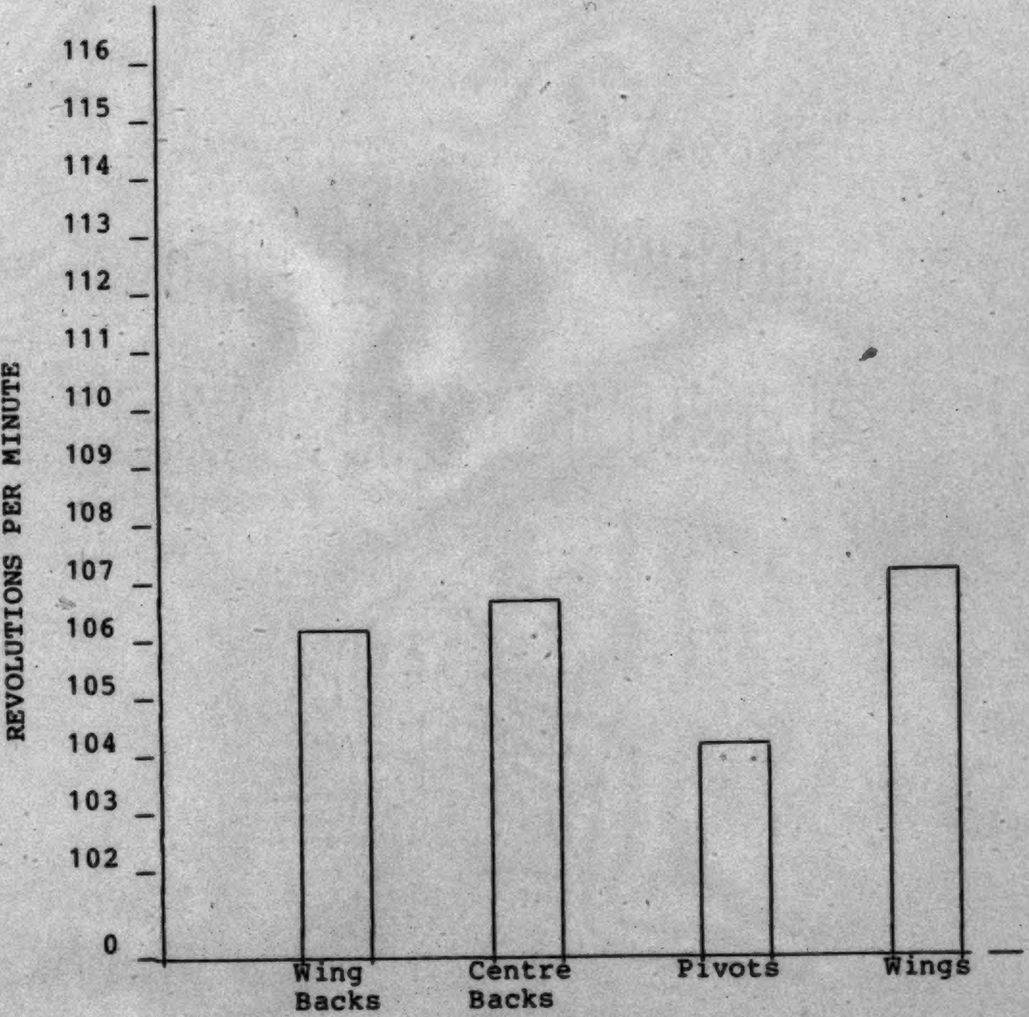


FIGURE 13

COMPARISON OF MEAN ANAEROBIC CAPACITY BY POSITION



POSITIONS

FIGURE 14

COMPARISON OF MEAN PER CENT BODY FAT BY POSITION

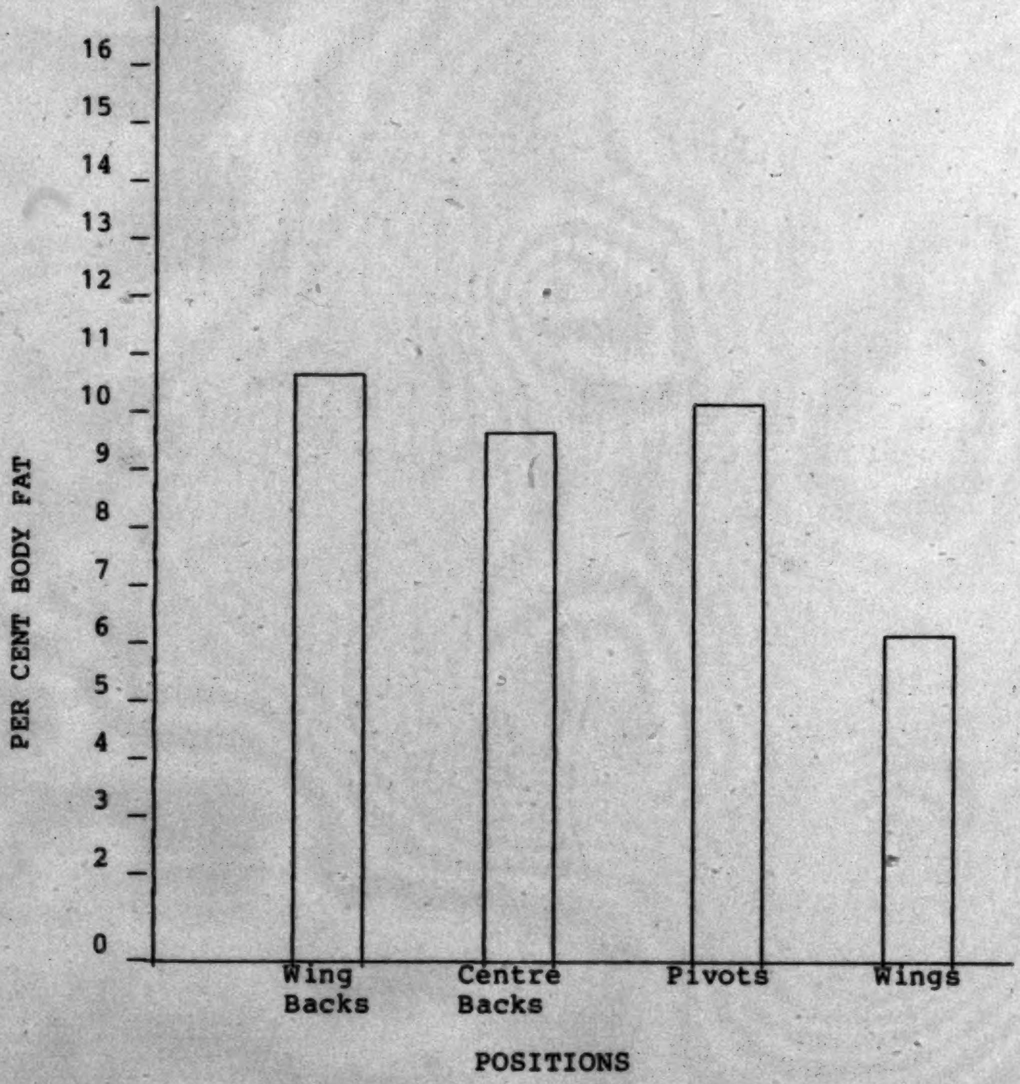


FIGURE 15

COMPARISON OF MEAN DISTANCE JUMP BY POSITION

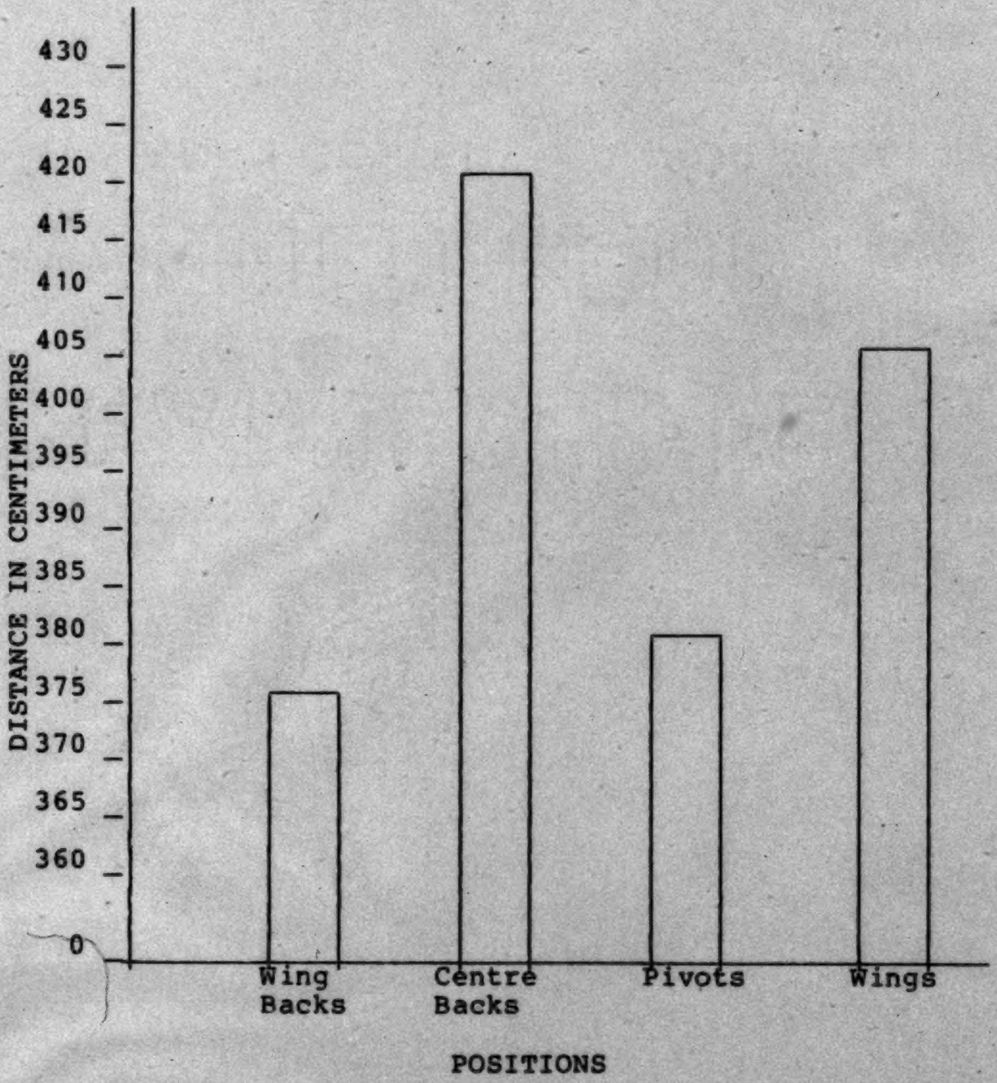


FIGURE 16

COMPARISON OF MEAN VERTICAL JUMP BY POSITION (in cm.)

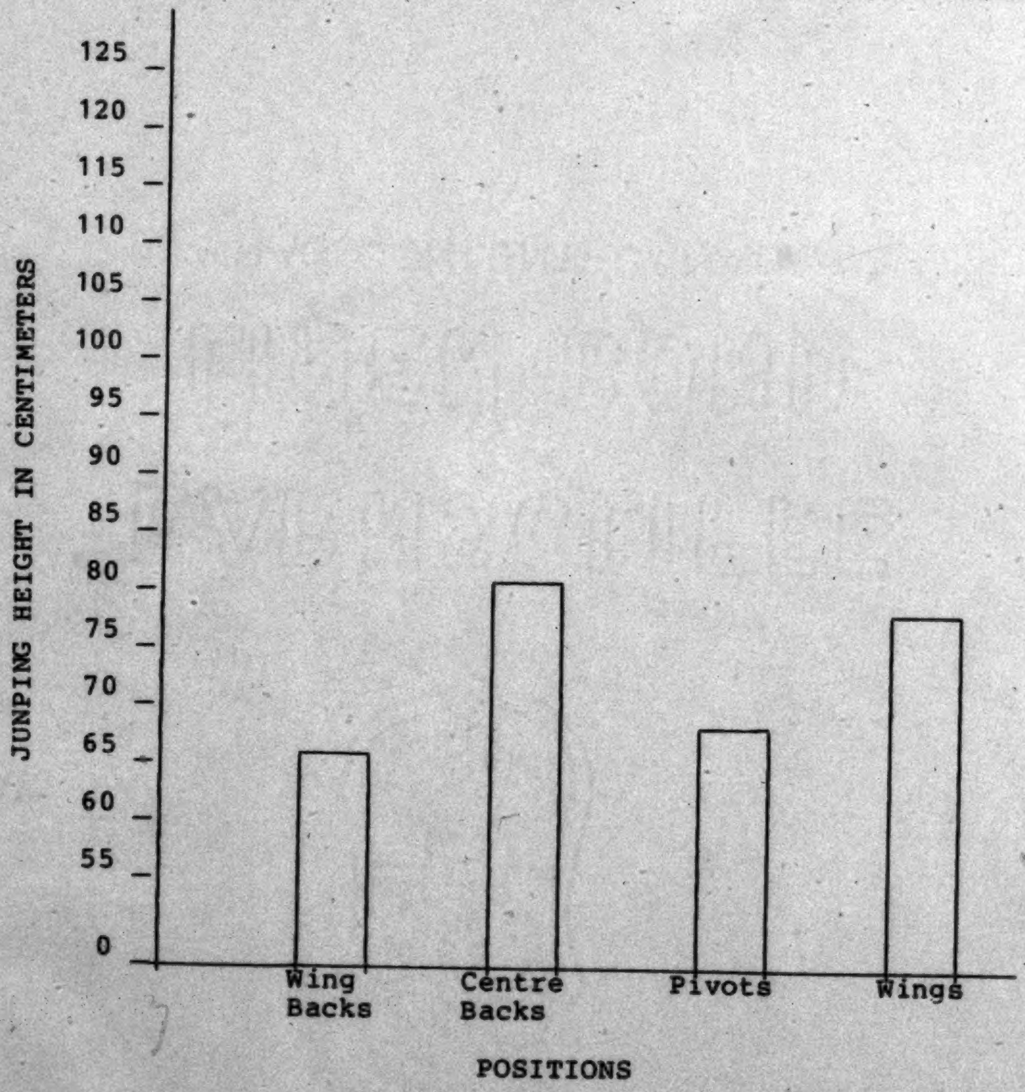


FIGURE 17

COMPARISON OF MEAN 10m SPRINT TIMES BY POSITION

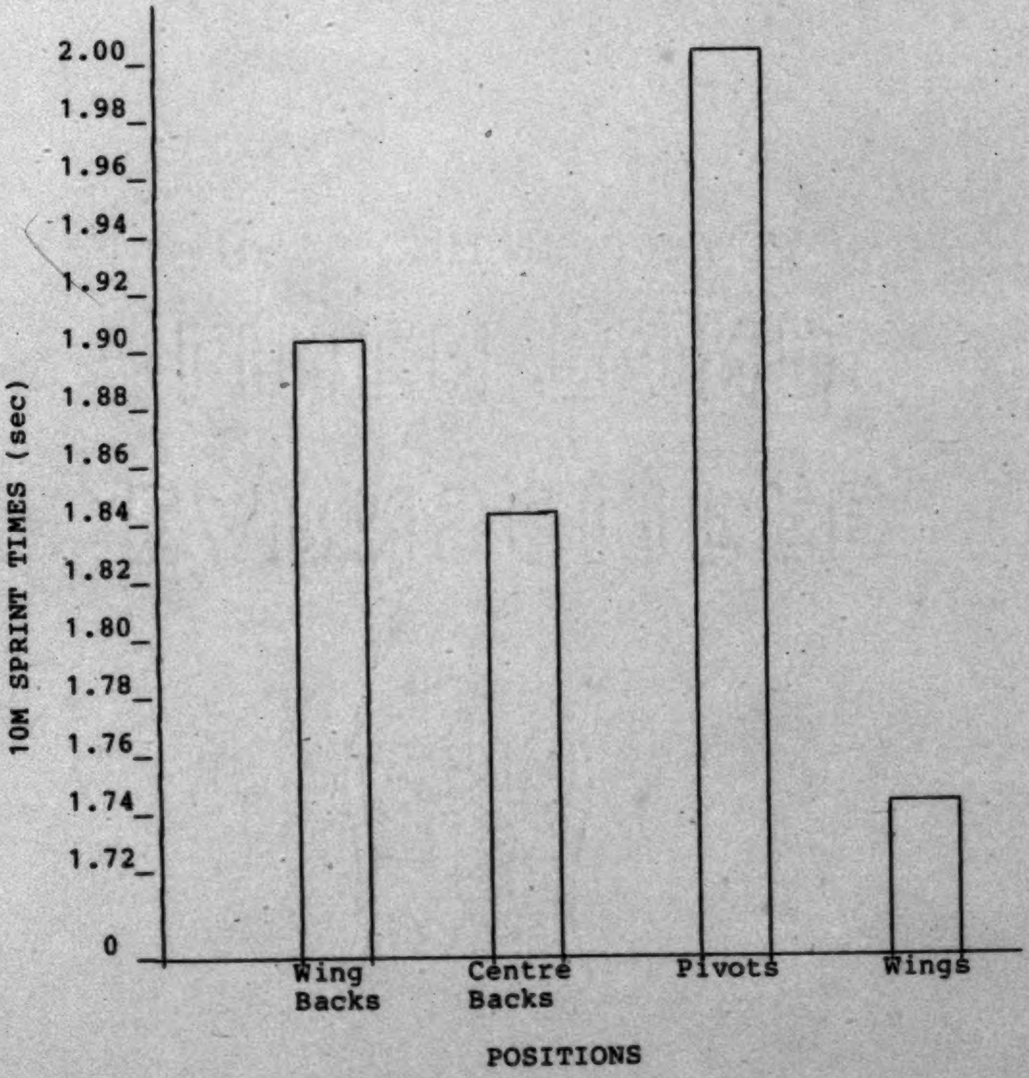


FIGURE 18

COMPARISON OF MEAN 40m SPRINT TIMES BY POSITION

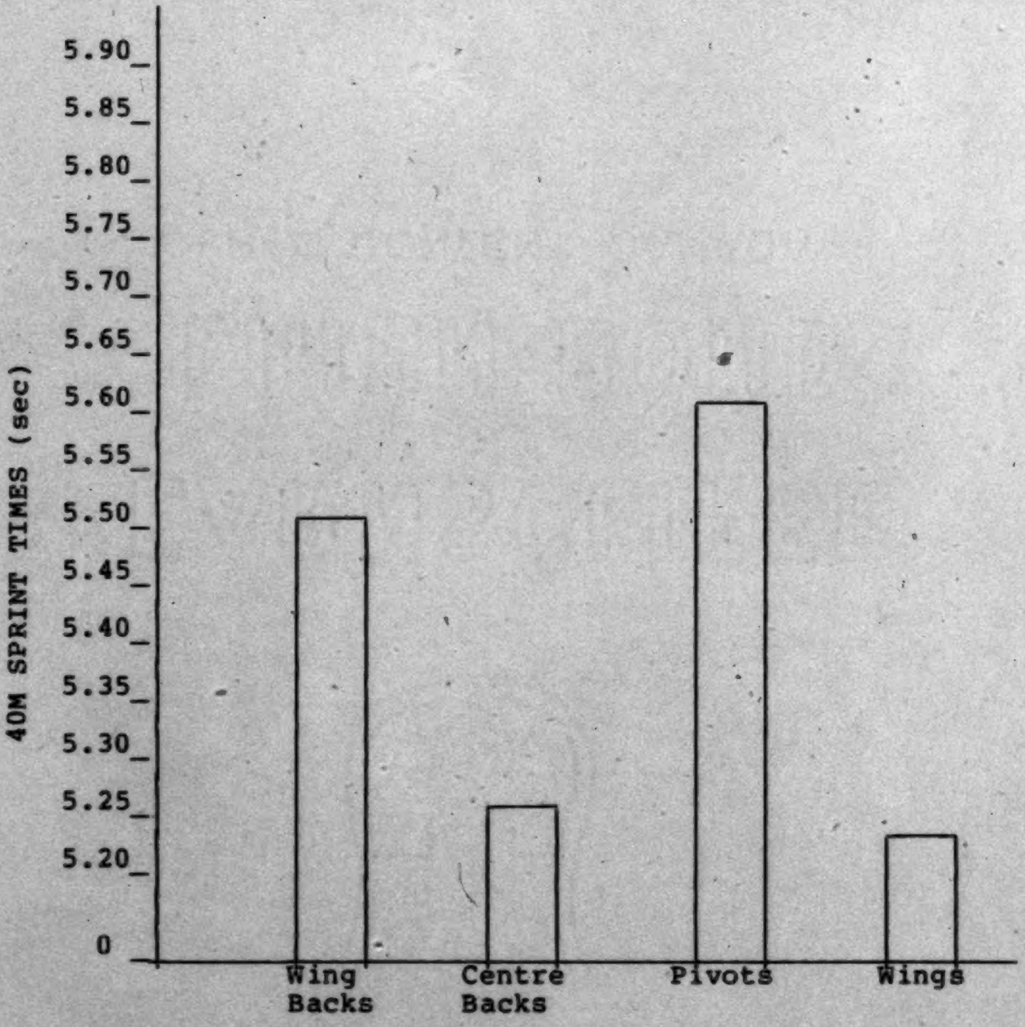


FIGURE 19

COMPARISON OF MEAN SHOT VELOCITY BY POSITION

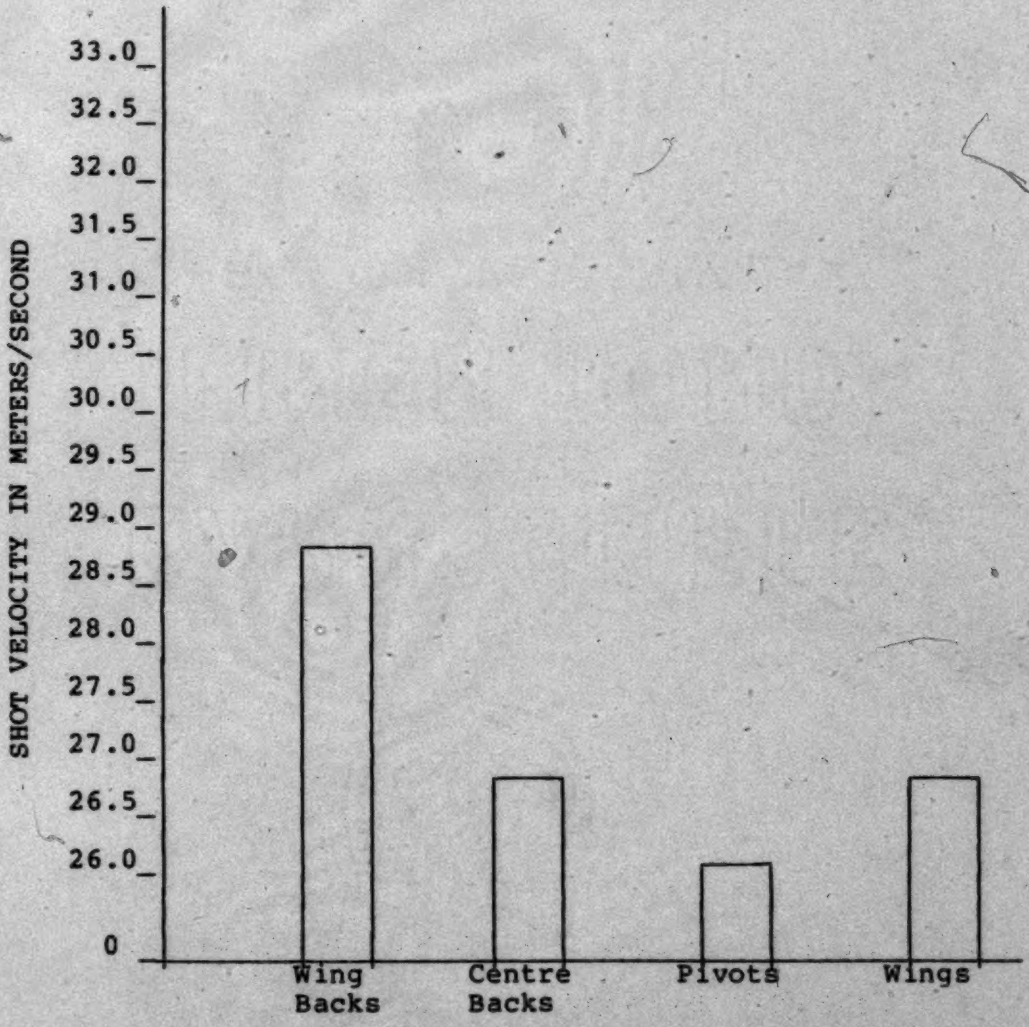


TABLE XII

AEROBIC TEST MEANS ACCORDING TO POSITION PLAYED

GROUP	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	OVERALL $\bar{X}$
WING-BACKS	$\bar{X}$=54.9 S= 6.6	$\bar{X}$=55.6 S= 3.73	$\bar{X}$=51.2 S= 5.04	$\bar{X}$=49.65 S= 5.06	$\bar{X}$=49.4 S= 5.97	$\bar{X}$=52.15 S= 2.92
WINGS	$\bar{X}$=54.3 S= 5.09	$\bar{X}$=52.9 S= 6.79	$\bar{X}$=50.50 S= 5.37	$\bar{X}$=50.05 S= 3.89	$\bar{X}$=51.58 S= 4.03	$\bar{X}$=51.58 S= 1.92
PIVOTS	$\bar{X}$=50.95 S= 1.77	$\bar{X}$=52.60 S= 4.95	$\bar{X}$=50.50 S= 0.42	$\bar{X}$=49.95 S= 0.35	$\bar{X}$=48.50 S= 1.13	$\bar{X}$=50.50 S= 1.49
CENTRE-BACKS	$\bar{X}$=60.3 S= 3.68	$\bar{X}$=57.90 S= 3.54	$\bar{X}$=50.00 S= 0.99	$\bar{X}$=54.85 S= 1.48	$\bar{X}$=53.40 S= 1.41	$\bar{X}$=55.30 S= 3.99

TABLE XIII

ANAEROBIC TEST MEANS ACCORDING TO POSITION PLAYED

GROUP	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	OVERALL $\bar{X}$
WING-BACKS	$\bar{X}$=101.25 S= 2.75	$\bar{X}$=106. S= 4.97	$\bar{X}$=106.25 S= 5.55	$\bar{X}$=106.25 S= 9.00	$\bar{X}$=108.88 S= 3.79	$\bar{X}$=105.85 S= 2.81
WINGS	$\bar{X}$=106.5 S= 4.95	$\bar{X}$=109. S= 1.41	$\bar{X}$=105. S= 4.24	$\bar{X}$=106.75 S= 3.89	$\bar{X}$=107.25 S= 1.77	$\bar{X}$=106.90 S= 1.44
PIVOTS	$\bar{X}$= 98. S= 0.0	$\bar{X}$=109. S= 7.07	$\bar{X}$=101. S= 0.0	$\bar{X}$=106.25 S= 0.35	$\bar{X}$=107.25 S= 1.06	$\bar{X}$=104.30 S= 4.61
CENTRE-BACKS	$\bar{X}$=105. S= 9.90	$\bar{X}$=109. S= 12.73	$\bar{X}$=absent S=absent	$\bar{X}$=105.25 S= 10.25	$\bar{X}$=105.25 S= 7.42	$\bar{X}$=106.13 S= 1.95

TABLE XIV

PER CENT BODY FAT ACCORDING TO POSITION PLAYED

GROUP	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	OVERALL $\bar{X}$
WING-BACKS	$\bar{X}$= 8.91 S= 3.08	$\bar{X}$=10.44 S= 3.25	$\bar{X}$=11.77 S= 3.36	$\bar{X}$=10.28 S= 2.70	$\bar{X}$=10.36 S= 5.01	$\bar{X}$=10.35 S= 1.01
WINGS	$\bar{X}$= 5.44 S= 2.04	$\bar{X}$= 6.63 S= 0.14	$\bar{X}$= 5.26 S= 1.85	$\bar{X}$= 6.93 S= 2.02	$\bar{X}$= 5.67 S= 2.31	$\bar{X}$= 5.99 S= 0.75
PIVOTS	$\bar{X}$= 8.78 S= 5.2	$\bar{X}$= 9.21 S= 6.25	$\bar{X}$=10.89 S= 6.54	$\bar{X}$=10.38 S= 6.61	$\bar{X}$=10.62 S= 4.98	$\bar{X}$= 9.98 S= 0.93
CENTRE-BACKS	$\bar{X}$= 8.20 S= 1.98	$\bar{X}$= 7.69 S= 3.83	$\bar{X}$= 9.20 S= 0.64	$\bar{X}$= 9.81 S= 0.78	$\bar{X}$= 8.83 S= 0.04	$\bar{X}$= 8.75 S= 0.83

TABLE XV

DISTANCE JUMP (in centimeters) ACCORDING TO POSITION PLAYED

GROUP	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	OVERALL $\bar{X}$
WING-BACKS	$\bar{X}$=375.3 S= 9.39	$\bar{X}$=377.2 S= 17.9	$\bar{X}$=380.1 S= 11.9	$\bar{X}$=363.2 S= 15.4	$\bar{X}$=379.7 S= 15.5	$\bar{X}$=375.1 S= 6.9
WINGS	$\bar{X}$=421.6 S= 14.4	$\bar{X}$=400.1 S= 5.4	$\bar{X}$=419.1 S= 27.0	$\bar{X}$=426.7 S= 0.0	$\bar{X}$=422.3 S= 8.1	$\bar{X}$=418.2 S= 10.4
PIVOTS	$\bar{X}$=375.9 S= 32.2	$\bar{X}$=374.7 S= 20.5	$\bar{X}$=384.5 S= 30.1	$\bar{X}$=383.5 S= 25.2	$\bar{X}$=374.7 S= 19.8	$\bar{X}$=378.7 S= 5.0
CENTRE-BACKS	$\bar{X}$=402.6 S= 41.3	$\bar{X}$=398.8 S= 53.9	$\bar{X}$=absent S=absent	$\bar{X}$=403.9 S= 50.3	$\bar{X}$=407. S= 31.4	$\bar{X}$=403.1 S= 3.4

TABLE XVI

VERTICAL JUMP (in centimeters)

GROUP	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	OVERALL $\bar{X}$
WING-BACKS	$\bar{X}$=64.8 S= 4.5	$\bar{X}$=65.9 S= 5.2	$\bar{X}$=67.5 S= 5.54	$\bar{X}$=63.2 S= 5.2	$\bar{X}$=65.7 S= 4.9	$\bar{X}$=65.4 S= 1.6
WINGS	$\bar{X}$=76.8 S= .89	$\bar{X}$=75.9 S= .46	$\bar{X}$=76.2 S= .00	$\bar{X}$=74.3 S= .89	$\bar{X}$=75.6 S= .89	$\bar{X}$=75.8 S= .94
PIVOTS	$\bar{X}$=66.7 S= .89	$\bar{X}$=66.4 S= 2.24	$\bar{X}$=69.9 S= 1.8	$\bar{X}$=64.8 S= .00	$\bar{X}$=68.0 S= 2.69	$\bar{X}$=67.1 S= 1.91
CENTRE-BACKS	$\bar{X}$=79.4 S=11.7	$\bar{X}$=77.9 S=11.3	$\bar{X}$=absent S=absent	$\bar{X}$=71.3 S=12.1	$\bar{X}$=77.5 S=10.8	$\bar{X}$=77.0 S= 2.6

TABLE XVII

SPRINT TEST (in seconds)

GROUP	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	OVERALL $\bar{X}$
WING-BACKS	$\bar{X}$=1.85 S=0.07	$\bar{X}$=1.86 S=0.06	$\bar{X}$=1.88 S=0.094	$\bar{X}$=1.83 S=0.10	$\bar{X}$=1.83 S=0.03	$\bar{X}$=1.85 S=0.02
WINGS	$\bar{X}$=1.73 S=0.01	$\bar{X}$=1.74 S=0.04	$\bar{X}$=1.77 S=0.03	$\bar{X}$=1.74 S=0.02	$\bar{X}$=1.74 S=0.01	$\bar{X}$=1.74 S=0.02
PIVOTS	$\bar{X}$=1.89 S=0.16	$\bar{X}$=1.91 S=0.13	$\bar{X}$=1.90 S=0.11	$\bar{X}$=1.88 S=0.140	$\bar{X}$=absent S=absent	$\bar{X}$=1.90 S=0.01
CENTRE-BACKS	$\bar{X}$=1.79 S=0.07	$\bar{X}$=1.80 S=0.13	$\bar{X}$=absent S=absent	$\bar{X}$=1.84 S=0.11	$\bar{X}$=1.84 S=0.06	$\bar{X}$=1.82 S=0.03

TABLE XVIII

40m SPRINT TEST (in seconds)

GROUP	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	OVERALL $\bar{X}$
WING-BACKS	$\bar{X}$=5.42 S=0.09	$\bar{X}$=5.44 S=0.09	$\bar{X}$=5.50 S=0.09	$\bar{X}$=5.57 S=0.07	$\bar{X}$=5.56 S=0.11	$\bar{X}$=5.50 S=0.07
WINGS	$\bar{X}$=5.20 S=0.08	$\bar{X}$=5.14 S=0.11	$\bar{X}$=5.21 S=0.06	$\bar{X}$=5.29 S=0.04	$\bar{X}$=5.26 S=0.07	$\bar{X}$=5.22 S=0.06
PIVOTS	$\bar{X}$=5.62 S=0.32	$\bar{X}$=5.58 S=0.23	$\bar{X}$=5.62 S=0.25	$\bar{X}$=5.63 S=0.25	$\bar{X}$=absent S=absent	$\bar{X}$=5.61 S=0.02
CENTRE-BACKS	$\bar{X}$=5.28 S=0.26	$\bar{X}$=5.29 S=0.34	$\bar{X}$=absent S=absent	$\bar{X}$=5.41 S=0.38	$\bar{X}$=5.44 S=0.29	$\bar{X}$=5.26 S=0.08

TABLE XIX

SHOT VELOCITY (m/second)

GROUP	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	OVERALL $\bar{X}$
WING-BACKS	$\bar{X}$=28.06 S= 1.46	$\bar{X}$=28.66 S= 1.35	$\bar{X}$=29.13 S= 1.30	$\bar{X}$=28.48 S= 1.70	$\bar{X}$=28.41 S= 1.42	$\bar{X}$=28.55 S= 0.39
WINGS	$\bar{X}$=26.86 S= 0.25	$\bar{X}$=27.32 S= 1.10	$\bar{X}$=27.46 S= 0.72	$\bar{X}$=26..99 S= 0.56	$\bar{X}$=27.19 S= 1.28	$\bar{X}$=27.16 S= 0.24
PIVOTS	$\bar{X}$=26.46 S= 0.08	$\bar{X}$=27.01 S= 1.23	$\bar{X}$=26.26 S= 0.82	$\bar{X}$=26.22 S= 0.59	$\bar{X}$=absent S=absent	$\bar{X}$=26.46 S= 0.36
CENTRE-BACKS	$\bar{X}$=26.10 S= 2.41	$\bar{X}$=27.54 S= 1.75	$\bar{X}$=absent S=absent	$\bar{X}$=26.98 S= 1.32	$\bar{X}$=26.50 S= 0.99	$\bar{X}$=26.53 S= 1.04